EVALUATION OF SUB-GRADE INFLUENCE IN RIGID PAVEMENT: A CASE STUDY IN THE SECTION OF THE RING ROAD FROM KALITY TO HANA MARIAM

Michael Ababu

A Thesis Submitted to

The School of Graduate Studies of Addis Ababa Science and Technology University in Partial Fulfillment of the Requirement for the Degree of Master of Science in Geotechnical Engineering.

ADDIS ABABA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

January 2019

CERTIFICATION

The thesis titled “Evaluation of Sub-Grade Influence in Rigid Pavement: A Case Study in the Section of the Ring Road from Kality to Hana Mariam” in Partial Fulfillment of the Requirement for the Degree of Master of Science in Geotechnical Engineering to School of Graduate Studies of Addis Ababa Science and Technology University.

______________________	___________________	_______________
Advisor	Signature	Date

Members of the Examining board:

1.	__________________	______________	_______________
	External Examiner	Signature	Date
2.	__________________	______________	_______________
	Internal Examiner	Signature	Date
3.	__________________	__________________	_______________
	Head, Civil Engineering Department	Signature	Date
4.	__________________	__________________	_______________
	ERA PG Coordinator	Signature	Date
5.	__________________	__________________	_______________
	Dean, College of Architecture and Civil Engineering Department	Signature	Date

ACKNOWLEDGMENT

My deepest gratitude goes to my advisor, Dr.Trufat Hailemariam, Assistant Professor, School of Earth Sciences, Addis Ababa University, his kind encouragement, understanding, criticism and guidance throughout the duration of the thesis. Special thanks to the Ethiopians Road Authority (ERA) for giving me the opportunity for the scholarships and department of civil and environmental engineering of Addis Ababa Science and Technology University.

I would also like to thank Dr. Melaku Sisay for his valuable support and guidance. Ethiopian Construction Design and Supervision Works Corporation Transport Design and Supervision Works Sector soil section laboratory staffs for their numerous supports on the laboratory work and AR CON design build company.

I would also like to thank Ethiopian Water Technology Institute for their valuable information and document supply.

Finally, my special thanks will goes to my family for all their concern and supports.

ABSTRACT

Most part of Ethiopia covered by black cotton soil. Roads that are constructed in such soils usually face failures; as their performance highly affected by the soil's weak strength and moisture sensitivity. This research is inspiring to define the influence of such soils in a rigid pavement of a ring road section between Kality ring road to Hana Mariam, in Addis Ababa.

The subgrade soil in the studied road section has seriously affected the pavement repeatedly and forced to make regular maintenance as well as design shift with different structural arrangements. Finally, Addis Ababa City Road Authority had changed the road pavement from flexible to rigid giving solution. However, the newly constructed rigid pavement faced different pavement distress such as; corner break, joint seal damage, cracking, lane-to-shoulder separation and improper drainage condition.

The pavement distresses categorized as low to high level of severity, the corner break damage has low level of severity the extent varies between 3m to 4m in length and an average width between 10cm to 15cm. the joint seal damage has low level of severity in transverse expansion joint and construction joints. The cracking categorized as transverse, longitudinal and alligator cracking has medium and low level of severity.

In defining the subgrade soil's influence in to the rigid pavement, field mapping of the pavement distress conditions, characterizing the subgrade soil's engineering properties through test pitting, soil sampling and laboratory testing were conducted. Accordingly, the laboratory test results of sieve analysis, CBR value, Atterberg Limits of subgrade soils and fill material samples shows that the material has poor quality to a make a reliable subgrade soil, according to AASHTO soil classification system and ERA manual. Thus, the rigid pavement distress is mainly associated the poor subgrade condition.

Generally, this research discuss on significance maintenance option of rigid pavement, consider extensively different factors to analysis road distress, compare contribution of problem causes and required laboratory tests are included.

LIST OF FIGURES Page No.

LIST OF TABLES Page No.

LIST OF ABBREVIATIONS & DEFINITIONS

AASHTO American association of state highway and transportation official's method

AACRA Addis Ababa city road authority

BH Bore hole

CBR California bearing ratio

C percentage of clay size finer than 0.002 mm by weight

CRCP Continuously Reinforced Concrete Pavements

CDV Corrected Deduct Value

DV Deduct Value

ERA Ethiopian Road Authority

EWTI Ethiopian Water Technology Institute

GI Group Index

Ip plasticity index

JUCP Jointed Unreinforced Concrete Pavements

JRCP Jointed Reinforced Concrete Pavements

LL liquid limit

LHS Light Hand Side

LL Liquid limit

MDD maximum dry density

NMC Natural Moisture Content

OMC optimum moisture content

PL Plastic limit

PCI Pavement Condition Index

RHS Right Hand Side

S Swelling potential

SCR Surface condition rating PI plasticity index

SP swelling potential

S swelling potential

W/5 liquid limit

Units

km Kilometer

mm millimeter

g/cm^3 Gram per centimeter cube

TABLE OF CONTENT……………………………………………………………Page No.

CHAPTER ONE

INTRODUCTION

1.1 Background and Justification of the Research

Most part of Ethiopia widely covered by expansive soil [1]. Heaving and shrinkage of subgrade soil has considerable effect on structures. This would results structural defects such as cracking settlement, petioles on a pavement structure. Repeated structural defects are experiencing mainly because of pavement sub grade problem, traffic condition and drainage condition of the road.

The nature of expansive soil affect the stability of structure built on it. The property of the soil is problematic for construction by changing the internal stability of the soil mass because of moisture variation; this would create cracks widely during the dry season and swell in the wet season. For such variable property of sub grade soil rigid pavement may take as an option in road construction stream.

Rigid pavement is composition of concrete and reinforcement bars can sustain heavy loading with minor defects that are not reflected, more skid resistance and safe. Reinforcement in concrete slabs is designed to counteract the tensile stresses caused by shrinkage and contraction due to temperature or moisture changes [2, 3].

Recently in Addis Ababa rigid pavement has taken as a maintenance option for different road distress replacing the defected stretch by concrete pavement, but still the road defects are observed.

1.2 Problem of Statement

The road section, which is investigate this research, was designed and constructed flexible pavement at the beginning, however the road section had suffered serious pavement deterioration and even with serious of pavement maintenance the problem persists. The Addis Ababa Road Authority had changed the road to rigid pavement to permanently solve the problem but the rigid pavement also suffered problem such as, Corner Breaks, Joint Seal Condition, Spalling, Cracking, Lane-to-Shoulder Separation on a pavement structure and improper drainage facility.

1.3 Objective of the Research

1.3.1 General Objective

The general objective of this research is to assess the influence of the subgrade soil in the rigid pavement distress.

1.3.2 Specific Objective

- To map the distress conditions of the selected rigid pavement;
- To characterize the surface and sub-subsurface profile of the selected road section;
- To understand the surface as well as the sub-surface water flow in respect of the selected road section;
- To evaluate the subgrade soil and drainage condition based on design criteria;
- To characterize the subgrade soil upon which the rigid pavement constructed;
- To evaluate contribution of sub grade soil for road distress;
- To evaluate of Pavement Condition;

1.4 Methodology of the Research

In order to achieve the above objectives of the research the following methodologies were adopted:

- Literature Review: Different literature sources including reference books, academic journals, seminars and research papers relating to expansive soil and rigid pavement were reviewed.
- Surface Mapping in the Rigid Pavement Distress Conditions: Topographic condition the research area with respect to surface and subsurface water flow, measure efficiency of drainage conditions and shoulder structures.
- Soil Sampling: Method of sampling has done for sub grade soil and replacement materials taken test pits are both disturbed and undisturbed soil samples. The sampling interval is depending on the level of road severity and standards [4, 5] to characterize the property of surface and sub-subsurface soil profile of the selected road section.
- Sample Preparation and Material Testing: A representative soil samples has taken form each test pits. Material tests such as; Natural Moisture content, Specific Gravity, Grain size analysis, Atterberg limit tests, Compaction Tests, California Bearing Ratio (3 point CBR) and swelling pressure done to determine soil property characterization and soil classification.
- Analysis and Interpretation: Based on collected data's and obtained laboratory test results, data's has been analyzed and interpreted to determine index properties, swelling potential, subgrade strength classes, evaluate the subgrade soil property and drainage condition to know contribution of sub grade in pavement structure distress.

1.5 Outcomes of the Research

The outcomes of the research helps to give idea on how to maintain effect of sub grade soils for any pavement structure failure.

1.6 Scope and Limitations of the Research

The scope of the research is to evaluate influence of sub grade soil on a rigid pavement of the road. The research has focused on collected data's and sample pits based on the degree of damages. In the present research, there were limitations on the availability documented design files, literatures and previous works extensively.

Absence of previous study, absence of required data for the research from owner (Addis Ababa City Road Authority), difficulty on sample taking were the main limitation of the research.

1.7. Organization of the Thesis

The research is organized in seven chapters.

Chapter 1 introduces background and justification, problem of statement, objective, methodologies, outcomes, scope and limitations and organization of research.

Chapter 2 discusses about review on black cotton soil, review on rigid pavement, and assessment of road condition.

Chapter 3 discusses on locations, topography, climatic condition, geology, drainage condition, land use and land cover, soil profile of research area.

Chapter 4 discusses on road condition and drainage condition survey of the research area.

Chapter 5 presents sub grade soil investigations and laboratory tests for sub grade soil.

Chapter 6 focuses discussion on test results, identification of cause of problems, evaluation of subgrade influence on rigid pavement.

Chapter 7 finalize on conclusions and recommendations

CHAPTER TWO

LITRATURE REVIEW

2.1. Review on Black Cotton Soil

2.1.1. Definition of Black Cotton Soil

Structures can be built on different soil properties. The nature of soil can be characterized by the mineral composition, chemical and physical property etc. The property of soil affects the structural capacity of soil and structures constructed on it. One of the determinant types of soil for such functions is expansive soil.

Expansive soils are clay soils with high plasticity nature. As the name of the soils suggests, these soils are known for their peculiar nature of expanding or shrinking when exposed to moisture changes. Commonly, they are known as black clays or in some regions as “black cotton” soils. The name black cotton came from the fact that the soils are found favorable in some regions for growing cotton [1, 6].

2.1.2. Impact of Black Cotton Soil

The impact of black cotton soil is shown on several parts of structure. Any structures, if their foundations are not adequately designed to withstand the stresses and strains caused by alternate heaving and shrinkage of the foundation soil, cracks, settlement, shear failure, tension crack, slope failure, brittle breaking, general shear failure, tilting and sliding of sturctures will happen. This would not only affect safety and aesthetics of the structures but also bring about additional financial burden to owners for repair if the structure is to be salvaged at all [1, 7].

2.1.3. Identification of Expansive Soil

Method of identification of expansive soil used to know the property of soil and impact on a structure built on it.

i) Visual Identification

Soils that have high swelling potential can be identified by visual observations in a stage of reconnaissance and preliminary investigation. It shows usually have black or grey in color, deep cracks observed , high dry strength and low wet strength and high stickiness and plasticity nature in wet season [6, 8].

ii) Identification Expansive Soil Using Single Index Method (Chen, 1988)

Simple soil property tests can be used for the evaluation of the swelling potential of expansive soils (Chen, 1988). Such tests are easy to perform and should be used as routine tests in the investigation of construction sites in those areas having expansive soil.

- Atterberg Limits Tests

Holtz and Gibbs (1956) demonstrated that the plasticity index, I_p, the liquid limit and W/5 were useful keys for determining the swelling characteristics of most clay. Since the liquid limit and the swelling of clays both depend on the amount of water clay tries to absorb, it is natural that they are related. The relation between the swelling potential of clays and the plasticity index has been established as given in Appendix 1

- Colloid Content

There is a direct relationship between colloid content and swelling potential as shown in Appendix 3. (Chen, 1988). For a given clay type, the amount of swell will increase with the amount of clay present in the soil.

The subgrade soil of research identified by the above method of soil identification system.it explains clearly how visually expansive soil can inspect and consider different soil index property approaches.

- California Bearing Ratio (CBR) Test

The CBR method is used for designing pavement structures and soil strength classification the test procedure is based on, American society for testing and materials, AASHTO T 193. This is carried out with 4 days soaking for socked CBR test type.

2.1.4. Classification of Expansive Soil

Classification of expansive soil can be done by correlating plasticity index using different approaches by different scholars. Based on those approaches the research evaluates the expansive potential of subgrade soil.

- Method of Seed at al.

Seed at al., (1962), describes the swelling potential is given as a function of the plasticity index by the formula and categorized as low to very high as shown in Appendix 4

$$S_P = 60k\,(I_P)^{2.4} \text{--Eq. 2.1}$$

Where: I_P is the plasticity index in percent,

S_P is swelling potential in percent

k is the constant, equal to $3.6*10^{-5}$

- Method of Skempton

Skempton (1953) measure the water holding capacity of clayey soils. The changes in the volume of a clayey during swelling or shrinkage depend upon the activity by the following expression and classified based on Appendix 5.

$$A = \frac{PI}{C} \text{-- Eq. 2.2}$$

Where: PI= plasticity index

C = percentage of clay size finer than 0.002 mm by weight.

- Method of Anderson et al [1]

Suggested empirical relation from which they were able to relate to degree of expansion with the plasticity index. Base on the result of swelling potential and plasticity index degree of expansion determined as shown in Appendix 6.

$$S = 0.23Ip - 3.12 \text{ -- Eq. 2.3}$$

Where S= swelling potential

Ip=Plasticity index

2.1.5. Evaluation of Sub Base and Sub Grade Soil

According to ERA manual evaluation of sub base and sub grade soil required to protect a drainage layer from blockage by a finer material or to prevent migration of fines and the mixing of two layers. The two functions are similar except that for use as a filter the material needs to be capable of allowing drainage to take place and therefore the amount of material passing the 0.075 mm sieve must be restricted [9].

The following criteria should be used to evaluate a sub base as a separating or filter layer:

a) The ratio $\frac{\text{D15(sub baselayer)}}{\text{D85(sub gradelayer)}}$ should be less than 5

Where:

D15 is the sieve size through which 15% by weight of the material passes

D85 is the sieve size through which 85% passes.

2.1.6. Soil Sampling

Soil samples are obtained during sub surface exploration to determine the engineering properties of the soils and rocks. Soil samples are generally classified into two categories [3]:

Disturbed samples: - These are the samples in which natural structure of the soil gets disturbed during sampling used to determine the index properties of the soil, such as grain size, plasticity characteristics, and specific gravity.

Undisturbed samples: - These are the samples in which natural structure of the soil and the water content is retained. These are used for determining the natural moisture content. The Undisturbed sample tried to take by Pipe Thin-walled sampler. In this research both method of sampling are used.

2.2. Review on Rigid Pavement

2.2.1. Concept of Rigid Pavement

The main structure of the pavement is a concrete slab which in relation to the flexible pavement, is the equivalent of the surface course, binder course, road base and sub-base combined. It is termed 'rigid' because this concrete slab does not deflect by itself under traffic load, Since the concrete slab provides both the surface course and the main structural strength of the rigid road, it must be constructed of high strength and high quality concrete and great attention must be paid to the surface finish in order to provide a good running surface with good skid resistance under all weather conditions.

Concrete expands and contracts as the air temperature rises and falls, so provision must be made to accommodate this variation, often referred to as 'thermal expansion and contraction', in the length of the road slab. Hence, transverse joints are provided at regular intervals as the purpose of these joints is to prevent the pavement from cracking under stress, the joint is designed to cater for the anticipated type of movement.

Rigid pavements (also called concrete pavements), as the name implies, are rigid and very strong in compression. The strength of the pavement is contributed mainly by a concrete slab, unlike flexible pavements where successive layers of the pavement contribute cumulatively. The rugose surface required for an adequate resistance to skidding in wet conditions can be provided by dragging stiff brooms transversely across the newly-laid concrete or by cutting shallow randomly spaced grooves in the surface of the hardened concrete slab [10].

The structural strength of a concrete pavement is largely within the concrete itself due to its rigid nature, because of the remarkable beam strength of concrete, heavy loads are distributed overlarge areas resulting in very low pressures on the subgrade. This makes it economically impractical to build up subgrade strength with thick layers of crushed stone or gravel. Performance has shown that high volume roads such as highways generally fail by the pumping and eroding of the subgrade at pavement joints and edges.

In these applications when granular sub bases are specified, they function not so much as a structural layer, but as a non-pumping layer to reduce the soil erosion under the pavement slab. Since low volume roads do not fail in this manner, they do not require sub bases to prevent subgrade pumping, in most cases these concrete pavements can be placed directly on the compacted subgrade [11].

2.2.2. Types of Rigid Pavements

According to ERA 2002 rigid pavements are categorized into three basic types depending on the level of reinforcement. The research pavement classified as explained below based on the construction material:

i) Jointed Unreinforced Concrete Pavements (JUCP)

ii) Jointed Reinforced Concrete Pavements (JRCP)

iii) Continuously Reinforced Concrete Pavements (CRCP)

2.2.3. Significance of Rigid Pavement

Rigid pavements have a capacity to resist unlimited loading, minor defects are not reflected, more skid resistance, safe, more economical for same projects at certain location, concrete layer is less thickness than other layers [12].

2.2.4. Design Criteria of Rigid Pavement

The design criteria of rigid pavements need to fulfill; the subgrade quality, the quality of the steel and concrete composing the slabs, the traffic condition, the environment (Moisture and temperature) and the notional design life.

A capping layer is required only if the CBR of the subgrade is 15% or less. For subgrade CBR values inferior to 2%, the subgrade material needs to be treated either by replacement or in-situ stabilization [5]. The research subgrade capacity evaluated based on requirement of subgrade strength of a pavement.

2.2.5. Rigid Pavement Practice in Addis Ababa

Rigid pavement practice is the final maintenance option which has taken by Addis Ababa City Road Authority for repeated flexible pavement damage. Now a day different road defects are observed mainly because of heavy traffic flow, poor drainage condition and improper sub grade condition treatment. In this research three road sections has taken for research area selection.

The following major criteria considered in selection of representative research area are [13, 14]:-

- The roads should fairly represent cement concrete roads.
- The roads should mostly utilizable sections and convey level of traffic loading.
- The roads level of severity and periodic maintenance.
- The roads drainage condition.

Table 2.1: Summary of test roads and selection criteria

No.	Name of test road	Length of stretch(m)	Current Pavement Maintenance condition	Current Level of pavement severity	Drainage condition	Traffic loading	Previous pavement severity condition
1	Zenebewerq squire to Ayer Tena	120m	Rigid pavement	Low	Poor	Medium	High
2	Minaye to Tor Hyloch	90m	Rigid pavement	Medium	Fair	Medium	High
3	Kality ring road to Hana Mariam	275m	Rigid pavement	High	Poor	High	High

From table 2.1 Kality ring road to Hana Mariam has relatively high pavement distress extent, poor drainage condition, high traffic loading, high length of stretch and the road supported by side masonry retaining wall.

Therefore; Kality ring road to Hana Mariam section has selected as representative research area based on the above criteria.

2.3. Road Distress Identification

Several types of data have to be collected to assess the road condition of a pavement; the evaluations include different road distress survey, identify problem cause and then propose maintenance option. This chapter will discuss on performance & failure criteria, methods of distress surveys, methods of pavement maintenance and analyses. The research subgrade evaluations are based on pavement condition survey and drainage condition survey which has direct relation with evaluation of subgrade influence.

2.3.1. Types of Pavement Distress

Pavement condition survey measured by different distress approaches and severity levels. Some pavement distress type's related to rigid pavement includes; Corner Breaks, Joint Seal Condition, Spalling, Cracks and Patching [16]. The research pavement distresses are presented based on as described below types of pavement distress.

i) Corner Breaks

A corner break is a portion of the slab separated by a crack, which intersects the transverse joint at one end of the slab and the longitudinal joint on one side of the slab and having a minimum dimension greater than six (6) inches (0.0254m). The crack makes approximately a 45^0 angle with the direction of travel and the level of severity measured as per Appendix 7.

ii) Joint Seal Condition

A joint seal is considered to be damaged whenever the seal will permit the infiltration of water and incompressible materials from the surface. Record the number of transverse and longitudinal joints which are fully sealed or unsealed and the level of severity measured as per Appendix 8.

iii) Spalling

Breaking or chipping of slab edges along and within two feet of a transverse joint. Spalls may be filled with asphalt concrete the severity level measured by Appendix 9.

iv) Cracking

Cracking are running predominantly across the pavement parallel and perpendicular to the pavement centerline. Surface distress data are classified as listed below, measured for severity, and quantified for extent. Classification, severity, and extent of these surface distresses elements used for calculation of SCR (Surface Condition Rating) [6].

- Alligator Cracks

Alligator cracking develops into a many-sided pattern that resembles chicken wire or alligator skin. It can occur anywhere in the road lane and categorized as Appendix 10.

- Longitudinal Cracking

Longitudinal cracking occurs predominantly parallel to the pavement centerline. It can occur anywhere within the lane and categorized as Appendix 11.

- Transverse Cracking

Transverse cracking occurs predominantly perpendicular to the pavement centerline and categorized as Appendix 12.

v) Lane-to-Shoulder Separation

A joint seal is considered to be damaged whenever the seal will permit the infiltration of water and incompressible materials from the surface. Record the number of transverse and longitudinal joints which are fully sealed or unsealed.

2.3.2. Causes of Pavement Distress

Different factors can mentioned to the causes of pavement deterioration such as drainage condition, subgrade soil condition, traffic condition and so on. Regarding to subgrade influence evaluation on a pavement, drainage condition and subgrade condition are important points on pavement distress causes assessment [11] and the causes of pavement distress of the research proceed based on as described below.

i) Drainage Condition

Drainage condition survey helps to identify the influence of drainage on a pavement performance and sub grade condition, document the drainage condition of a pavement, asses the effectiveness of drainage. Some of components of drainage condition surveys are [17, 18]:

- Topography and Cut/Fill

Topographic characteristics of the area should be determined to analyze the concentration and flow direction of surface and subsurface flow.

- Cross-sectional Capacity Drainage

The cross section of drainage should be determined to know the capacities of drainage can safely drain out the upcoming flows from any directions. The slope of a pavement and shoulder also indicates the flow of runoff direction to side ditches.

- Condition of Ditches

The condition of ditches determined by measuring the extent of threshold condition exists in the ditch and how much drainage outlets or inlets are blocked.

ii) Subgrade Condition

The sub grade condition identification and classification are discussed on the above section. The causes of pavement distress are also related to the bearing capacity of sub grade which is the CBR value. CBR is the most widely used methods to know the strength of subgrade soil and for designing pavement structures. The test procedure is based on, American society for testing and materials, AASHTO T 193.

2.3.3. Pavement Distress Analysis

The pavement distress analysis will be done according to pavement distress type and pavement subgrade soil classification. Each types of distress has level of severity and subgrade soil classification from low to high by the degree ratting as shown in Appendix 1to12. The degrees of severity of the research are based on this method of analysis.

2.3.4. Impact Analysis of Pavement Distress

Impact of pavement distress can be seen from service time of the road. It is feasible to design rigid pavements for longer design lives, up to 60 years [19] but by the different causes the road shows various types of pavement distress which may result pavement failure, poor riding quality, traffic problem etc. generally the road will not give the required service.

2.3.5 Evaluation of Pavement Condition

The Pavement Condition Index (PCI) is a measured condition rating system developed by the US Army Corps of Engineers and adopted by the American Public Works Association and American Society for Testing and Materials (ASTM). The PCI is a numerical indicator that rates the surface condition of the pavement from 0 to 100, where 0 it's the worst possible condition and 100 the best possible condition. The PCI provides a measure of the present condition of the pavement based on the type and severity of distresses observed on the surface of the pavement which also indicates the structural integrity and surface operational condition (localized roughness and safety). The PCI is a subjective method in terms of quantifying the structural and functional condition of the pavement, as it neither measures the bearing capacity, nor quantities the level of surface characteristics but provides feedback on pavement performance for validation or improvement of current pavement design and maintenance procedures [20].

Table 2.2: Summary of standard PCI rating scale

No	PCI value	Rating
1	85-100	Good
2	70-85	Satisfactory

3	55-70	Fair
4	40-55	Poor
5	25-40	Very poor
6	10-25	Serious
7	0-10	Failed

- **Calculation of PCI**

For each unique combination of distress type and severity level, it has to be recorded the number of slabs in which they occur.

- **Calculation of Density**

To calculate the percentage of density, divide the number of slabs recorded from a specific distress by the total number of slabs in the sample unit and multiply by 100.

$$\text{Density } \% = \frac{\text{No.of Distressed no.slab}}{\text{Total no slab}}$$

- **Calculation of Deduct Value**

To determine the Deduct Value (DV), there are DV graphic curves for most of the distresses. As presented at Appendix I graphic, there is a curve for each severity level, from the density and the severity level curve it is possible to determine the DV (see figure 4.4) by drawing a vertical line and a horizontal line starting at the intersection between the vertical line and the curve to the axis of the DVs.

- **Calculation of Corrected Deduct Value**

The Pavement Condition Index (PCI) is given by:

PCI=100-HCDV

Where:

100 -- Maximum PCI

HCDV- Highest Corrected Deduct Value

To determinate the PCI, first the CDV is determinate, but if none or only one individual DV is greater than five, the total DV is used in place of the maximum CDV in determining PCI.

Otherwise, if more than one DV is bigger than five, in order to determine the maximum CDV another procedure is followed.

First, the maximum allowable number of distresses, "m", is calculated.

$$m = 1 + \frac{9}{95} * (100 * HDV) <= 100$$

Where:

HDV – Highest deduct value.

Secondly, the "m" highest DVs have to be entered on line 1 of the following table, including the fraction obtained by multiplying the last DV by the fractional portion of "m". If less DVs are available, enter all of the DVs.

Sum the DVs and enter it under "Total". Count the number of DVs greater than five and enter it under "q".

Third, to determine CDV the appropriate correction curve included in Appendix II has to be used, and as done before to determine the DV, with the "Total" and the "q" determine CDV. Copy DVs on current line to next line, changing the smallest DV greater than five to five. Repeat the same procedure to determine CDV until "q"=1 (see table 4.7).
Finally the PCI is given by:

PCI=100-HCDV

2.4 Previous Researches

Different researches were done related to subgrade evaluations on road, pavement distresses condition survey on Addis Ababa city arterial roads, geotechnical characterization of sub grade materials of the road and so on.

i) Performance of roads constructed on black cotton subgrade soil with respect to replacement materials type and replacement depth, a case study on Modjo - Edjere road considered using a combination of different soil laboratory parameters such as liquid limit, plasticity index, natural water content, swelling pressure, CBR value and evaluating the replacement depth material in black cotton soil subgrade [21].

ii) Pavement distresses on Addis Ababa city arterial roads, causes and maintenance options. Different road distress types in five test flexible pavements, considered using a combination of swelling pressure and CBR value soil laboratory results. The pavement evaluation results were based on functional, structural, drainage and preliminary design category [22].

iii) Geotechnical characterization of sub grade materials for pavement construction, a case Study on Aposto – Wondo – Negele road upgrading project, Contract 2: IrbaModa ~ Wadera road construction. Grain size distributions, Atterberg limits, the group index (GI) methods, the density moisture, CBR tests laboratory tests were done to characterize and classified the subgrade condition and done pavement design review [23].

Those researches focused on the flexible pavement of sub grade soil condition evaluation. This researches study on rigid pavement distress identification and subgrade soil evaluation.

Generally the literature review has four main parts; review on black cotton soil, review on rigid pavement, road distress identification and previous researches. Each parts includes different sub contents these are; definition of black cotton soil, impact of black cotton soil, identification of expansive soil, classification of expansive soil, evaluation of sub base and sub grade soil, soil sampling, concept of rigid pavement, types of rigid pavement, significance of rigid pavement, design criteria of rigid pavement, rigid pavement practice in Addis Ababa, types of pavement distress, causes of pavement distress, pavement distress analysis and impact analysis of pavement distress and evaluation of pavement condition.

CHAPTER THREE

THE STUDY AREA

Introduction

Akaki Kality is one of the sub cities of Addis Ababa which is located at southern part of Addis Ababa and cover total area of 108.08km^2. Because of geographical location of the area it serves as entrance and exit of the city for different vehicles. As result of this, the roads were exposed for high traffic movements this has made one factor for frequent damage of the roads and serious maintenance of the roads are shown for a long period of time.

3.1. Location of Research Area

Kality ring road located at the entrance of Kaity town connect four places; Stadium or Bole to Kality, Stadium or Kality to Hana Mariam, Bole to Hana Mariam and Stadium to Bole and vice versa. The study area of the road is a rigid pavement that connects Stadium or Kality to Hana Mariam as shown figure 3.1.

Table3.1: The geographical position the research stretch

No	**Station(km)**	**Latitude(N)**	**Longitude(E)**
1	0+000	$08^0$56.067’	$038^0$45.883’
2	0+275	$09^0$00.251’	$038^0$52.178’

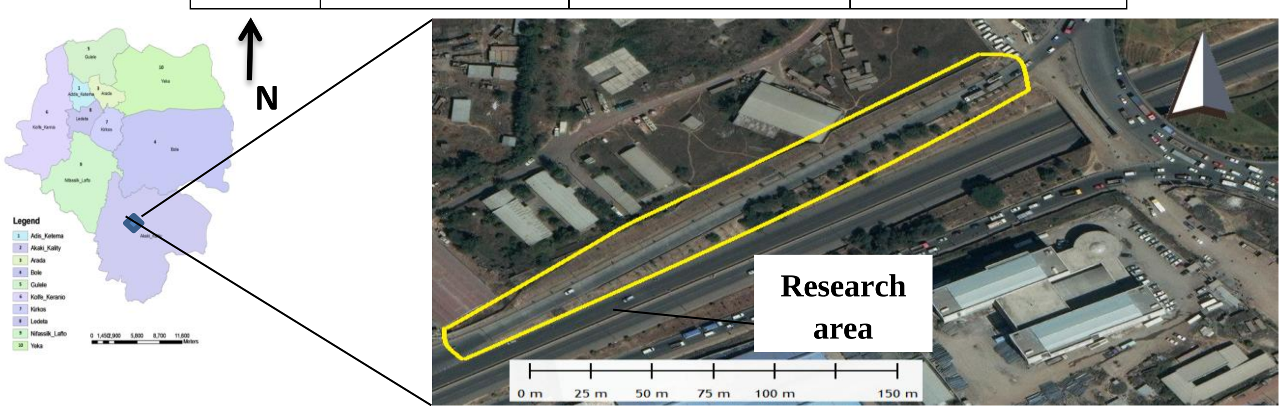


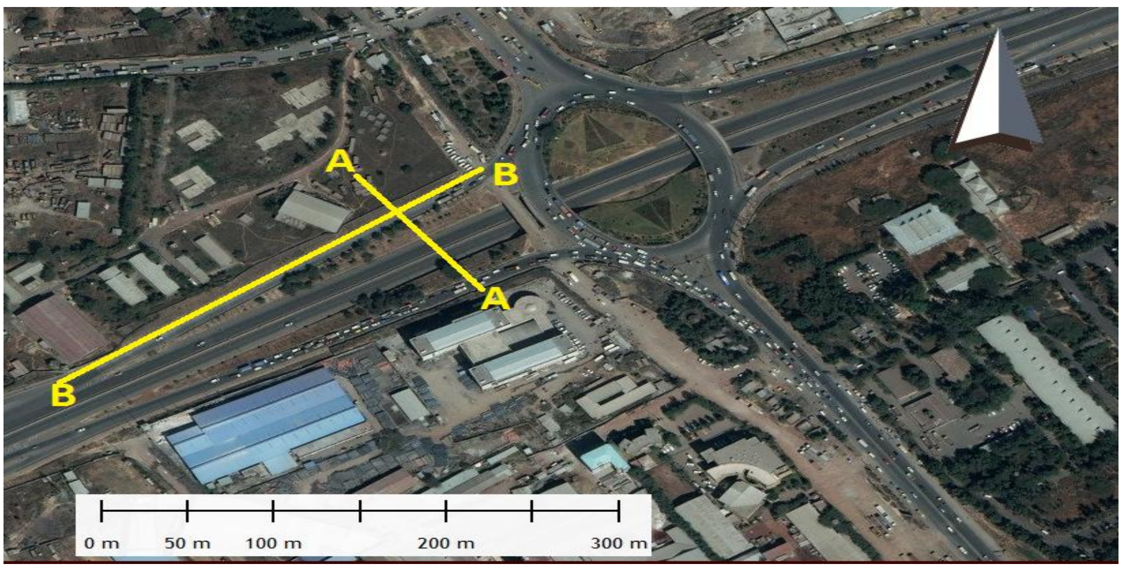
Figure 3.1: Satellite image of the research area (Source: from Google earth map 2012)

3.2. Topography of Research Area

The terrain condition of the road classified as flat and the total length of the rigid pavement is 275m.

Table3.2: According to ERA terrain classification the road classified as flat

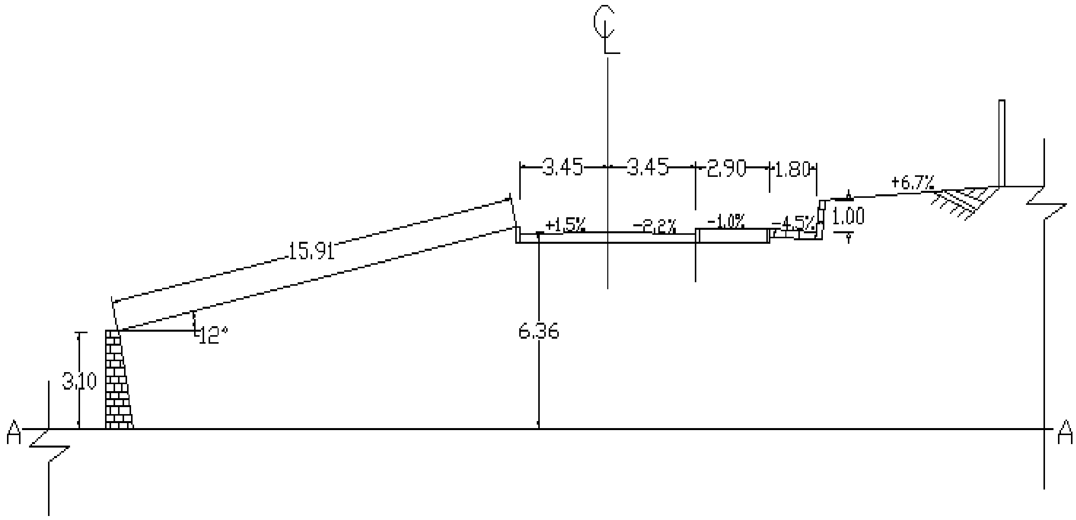
No.	Station(km)		Slope	Category
	From	To		
1	0+000	0+275	3.40%	Flat



a) Top view of the road (Source: from Google earth map 2012)

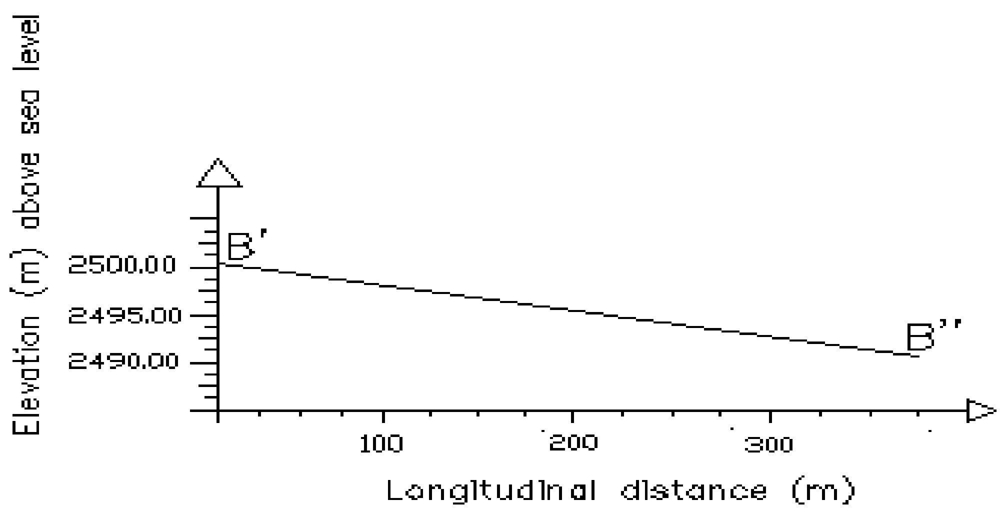
The figure 3.2a shows the road serves high traffic movement from those four main directions and different governmental institutions are placed.

From transversal section of the research pavement as shown the figure 3.2b surface runoff cannot properly drain out because of insufficient drainage placement, the topographic view of the section downward to the left direction.



b) Pavement transversal gradients at section A-A and station 0+034m, all dimensions are in meter

The longitudinal section of the research pavement downward to the left direction by a slope of 3.4%, the elevation level and station are presented in figure 3.2c.



c) Pavement sections B’-B” gradient at center, all dimensions are in meter

Figure 3.2: Topography of the research area

3.3. Climate of Research Area

Climate is governing factor for soil formation and changeable property of expansive soil. Ethiopia is classified into five climatic zones. These include "Kur" (Alpine), above 3000m mean sea level; "Dega" (Temperate), 2300m to about 3000m; "Weina Dega" (Sub tropical), 1500m to about 2300m; "Kolla" (Tropical), 800m to about 1500m and "Bereha" (Desert), less than 800m.The station is located at elevation of 2400m which categorized "Weina Dega" (Sub tropical) [20].

3.3.1. Temperature

The observed mean monthly and annual average maximum and minimum temperatures of Akaki Kality Addis Ababa data obtained from National Meteorological Services Agency between 1951-2004 is given in Table 3.3.

Table 3.3: Monthly and Annual Average Maximum and Minimum Temperatures of Akaki Kality Addis Ababa (1951-2004)

Description	**Month**												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual Average**
Mean. Temp.(^{o}C)	26.5	27.6	28	27.8	28.2	25.9	24.2	24	25.1	26	25.8	25.9	26.25

The Annual Average temperature is 26.25 ^{o}C,

3.3.2. Rainfall

The annual mean rainfall Akaki Kality Addis Ababa (1951-2004) is 1110mm. obtained from National Meteorological Services is given below in Table 3.4.

Table 3.4: Mean Monthly and Mean Annual Rainfall of Akaki Kality Addis Ababa (1951-2004)

Description	Month												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Ann. Avg.**
Rainfall(mm)	14	36.8	67.5	91	67.1	123	264.1	283.9	131.1	24.5	3.8	3.1	1110

The Mean Annual Rainfall is 1110mm.

3.4. Geology of Research Area

Addis Ababa widely covered by highly expansive black cotton soil. Parent materials associated with expansive soils are either basic igneous rock or sedimentary rocks. Igneous rocks are formed by decomposition of feldspar and pyroxene and sedimentary rocks are constituents of the rock itself [7]. The research area has parent material of Bofa Basalts (Akaki Basalt). It outcrops southward from Akaki River where these rocks appear in the form of boulders reaching a thickness of up to 10 m. These rocks are restricted and dominated in the southern and southeastern part of the Addis Ababa city [21].

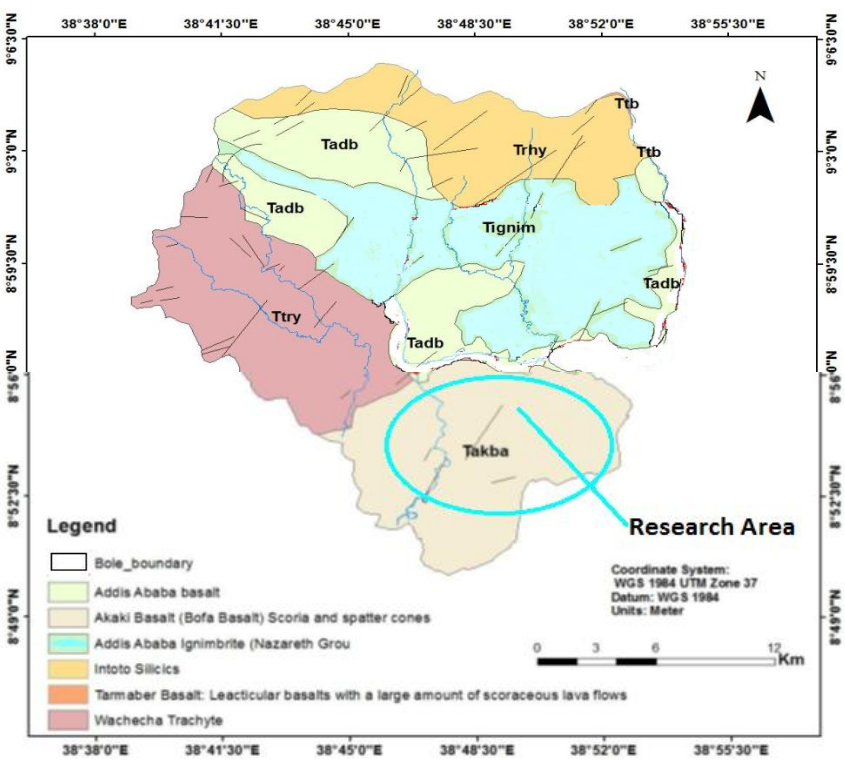


Figure 3.3: Geology of the research area (Source: from thesis Eyrusalem Abdulkader, 2015)

3.5. Drainage Condition of Research Area

The sub surface drainage of Addis Ababa flows under the soil as shown in figure 3.4 depends on the landscape map of the area. There is a concentration of flow lines at Akaki Kality sub city and research area as shown in figure 3.4, it can observed that there is ground water development and flow which helps for weathering, decomposition and transportation parent material to expansive.

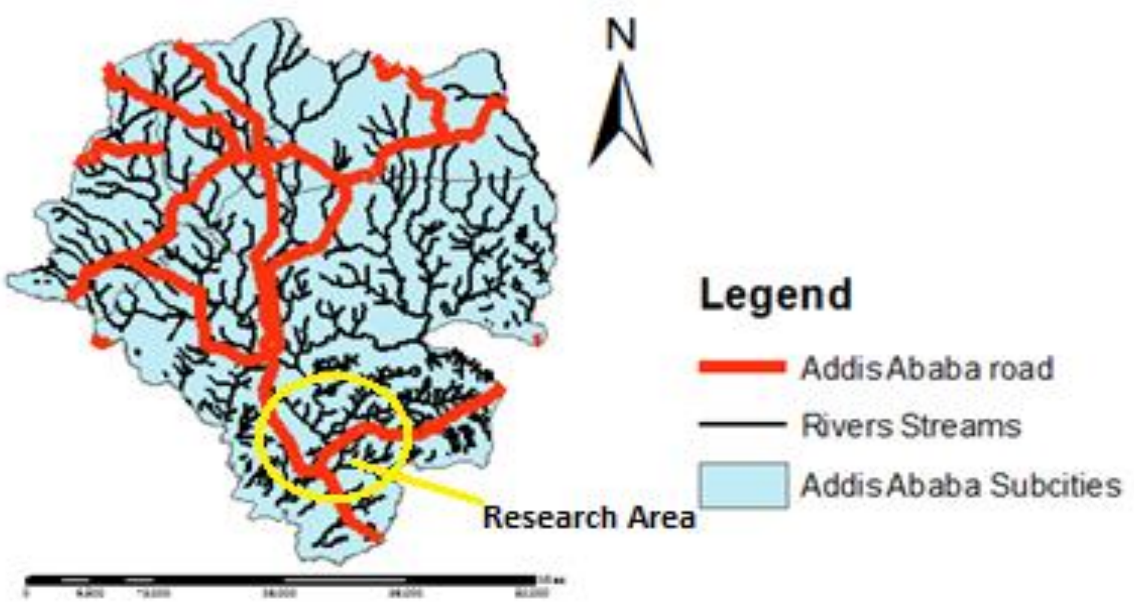


Figure 3.4: Drainage condition of the research area (Source: from Arc GIS, 2017)

3.6. Land Use and Land Cover of the Research Area

During the field observations and investigations, it has been shown that the side road from km 0+000 to km 0+275 is covered with scattered artificial and natural plants.

Figure 3.5: Land cover of the research area

3.7. Soil Profile of Research Area

From the visual inspection of the site, the left side of the road is embankment covered by trees and grass and the right side of the road is border of Ethiopian Water Technology Institute. The predominant soil type observed for almost the whole side of the road covered by black cotton soil which is usually considered as unsuitable material for any structural purpose.

a) Fill material at 0+034 km RHS

b) Fill material RHS at 0+175 km

Figure 3.6: Soil profile of the research area

CHAPTER FOUR

PAVEMENT CONDITION SURVEY

Introduction

Pavement condition survey includes road condition assessment, drainage condition evaluation and traffic condition survey [24]. Serviceability performance evaluation of the road gives information on the capability of the pavement structure comfortable and safe for vehicles [25]. Those are the factors influence for pavement deterioration assessment.

4.1 Road Condition

Introduction

The road condition survey conducted to evaluate serviceability of the road and identifying the general defects of the road. Corner Breaks, Joint Seal Condition, Spalling, Cracking and Lane-to-Shoulder Separation, are the main distresses observed on the pavement. It's necessary to identify the location of defects, extent of distresses and categorize the degree of severity of the whole extent of the road from the starting of the rigid pavement to the end and to know the types of pavement distress and level of failure occurred that influence the performance of the road [14].

4.1.1. Measurement of Road Distress

i) Corner Breaks

The corner breaks of the pavement mainly classified in three stations each corner breaks appeared on one slab bay expansion joint as shown in figure 4.1, the damage extent varies between 3m to 4m in length and has an average width between 10cm to 15cm as explained in a table 4.1. It contents; station, number of broken slab, damage extent in length and average width.

Figure 4.1: Corner breaks

Table 4.1: Summary of corner breaks

No.	Location	No. Broken Slab	Damage extent in length(m)	Damage extent average width (cm)	Level of severity
1	0+120 RHS	3	4m	15cm	Low
2	0+050 LHS		3m	10cm	Low
3	0+190 RHS		3m	13cm	Low

ii) Joint Seal Damage

The road has transversal wearied out a sealing groove expansion joints and construction joints as shown figure 4.2. Transverse expansion joint and construction joint are types of joint exist on a pavement. From those recorded 10 levels of transverse joints in table 4.2 the 5 are fully damaged of covered seal and the others are more than 50% sealed coverage are damaged.

Figure 4.2: Joint seal damage

Table 4.2: Summary of joint seal damage

No.	Description	Joint seal type	Location(km)	Sealed extent in percent (%)	Level of Severity
1	Expansion joint	Transverse	0+016	100	High
2	Expansion joint	Transverse	0+040	50	High
3	Expansion joint	Transverse	0+070	100	High
4	Expansion joint	Transverse	0+103	75	High
5	Expansion joint	Transverse	0+140	100	High
6	Expansion joint	Transverse	0+170	100	High

7	Expansion joint	Transverse	0+200	100	High
8	Expansion joint	Transverse	0+220	50	High
9	Expansion joint	Transverse	0+240	50	High
10	Expansion joint	Transverse	0+260	75	High

iii) Cracking

The cracks were varying from hair line cracks to easily visible cracks presented in representative way. The failed sections were identified visually and recorded manually, an approximate measurement of the width and length of cracks were tabulated in table 4.3.

Hence, depending on the observed distress pattern as shown in figure 4.3 below the cracks are classified as follow:

- Transverse cracking in a direction perpendicular to the center line covers extensively on the pavement has an average length 5.6m and width of 5.1mm.
- Longitudinal cracking in a direction parallel to the center line covers an average length 1m and width of 4mm.
- Alligator cracking in a pattern chicken wire structure covers an average length 0.35m and width of 4.5mm.

Figure 4.3: Surface cracking

Table 4.3: Summary of cracking

No.	Station(km)	Average Crack Length (m)	No. of Slab	Average Crack Width (mm)	Observed distress type	Level of severity
1	0+003	7	5	4	Transverse cracking	Medium
2	0+004	5		4	Transverse cracking	Medium
3	0+008	7		3	Transverse cracking	Medium
4	0+014	2		6	Transverse cracking	Medium
5	0+019	7		5	Transverse cracking	Medium
6	0+026	3		3	Transverse cracking	Medium
7	0+035	3		6	Transverse cracking	Medium
8	0+037	7		3	Transverse cracking	Medium
9	0+045	7		5	Transverse cracking	Medium
10	0+110	7		9	Transverse cracking	Medium
11	0+135	7		8	Transverse cracking	Medium
12	0+010-0+150	1	6	4	Longitudinal cracking	Low
13	0+055-0+155	0.3	9	4	Alligator cracking	Low
14	0+170-0+275	0.4		5	Alligator cracking	Low

iv) Lane-to-Shoulder Separation

Lane-to-shoulder separation indicate the space between lane and shoulder. As observed figure 4.4 proper expansion joint sealers don’t provided and the extent of separation is recorded in average length 44.5m and width 26.6mm as shown in table 4.4.

Figure 4.4: Lane-to-shoulder separation

Table 4.4: Summary of lane-to-shoulder separation

No.	Station(km)	Length (m)	Width (mm)	No. Slab	Sealing condition
1	0+023-0+070 LHS	47	30	2	Unsealed
2	0+077-0+110 LHS	33	40	2	Unsealed
3	0+044-0+097 RHS	53	10	2	Unsealed

4.1.2 Evaluation of Pavement Condition

To compute PCI the density of the distress should be first calculated, so based on the type of defects the value of density presented.

- Corner breaks

Table 4.5: Corner breaks density

No.	Level of severity	Number of slab	Total number of slab	Density%
1	Low	3	10	30

- Cracking

Table 4.6: Summary of cracking density

No.	Type of distress	Level of severity	Number of slab	Total number of slab	Density%
1	Transverse	Low	5	10	50
2	Longitudinal	Low	6		60
3	Alligator	Low	9		90

- Lane-to-Shoulder Separation

Table 4.7: Lane-to-Shoulder Separation density

No.	Level of severity	Number of slab	Total number of slab	Density%
1	Unsealed	6	10	60

Calculation of Deduct Value

The deduct value also needed for PCI calculation this would take from graphs by associating severity level and distress density. Calculation of Corner breaks, Cracking and Lane-to-Shoulder separation calculated from presented Appendix 13, 14 &15 graphs by taking severity Level and distress density.

Table 4.8: Summary of Deduct Value

No	Type of distress		Level of severity	Density%	Deduct Value
1	Corner breaks		Low	30	21
2	Cracking	Transverse	Low	50	21
3		Longitudinal	Low	60	22
4		Alligator	Low	90	24
5	Lane-to-Shoulder Separation		Low	60	14

Calculation of Corrected Deduct Value

Corrected Deduct Value needed for calculation PCI

Calculate the maximum allowable number of distresses, “m”,

$$m=1+\frac{9}{95} * (100 - HDV) <= 100$$

$$m=1+\frac{9}{95} * (100 - 24) <= 100$$

m=8.2

This means that only six distresses have to be considered for this PCI calculation

Table 4.9: Summary of Corrected Deduct Value

No	Deduct Values						Total	q	CDV
1	24	22	21	21	14	14*0.2=2.8	104.8	5	67.9
2	24	22	21	21	5	14*0.2=2.8	95.8	4	66.1
3	24	22	21	5	5	14*0.2=2.8	79.8	3	60.5
4	24	22	5	5	5	14*0.2=2.8	63.8	2	54.1
5	24	5	5	5	5	14*0.2=2.8	46.8	1	46.8

Finally the PCI:

PCI=100-HCDV

PCI=100-67.9=32.1

As per table 2.2 the PCI result is categorized in very poor rating.

4.2. Drainage Condition Survey

Introduction

The function of the drains (or ditches) side of road is to collect water from the road surface and the adjacent areas lead to an exit point where it can be safely discharged. The sides drain need to have sufficient capability to collect all rainwater from the road surface and dispose it quickly in a controlled manner to minimize damage [17].

4.2.1. Drainage Condition According to Topography

The road classified as flat from topographic classification of the road. The ditch has placed only on the right side of a road starts from station 0+061 to 0+238 by a bed slope of 0.5%. It is triangular paved ditch as shown figure 4.5. Most part of the ditch stretch has covered by eroded side slope soil and plants on it.

From topography view of the area the drainage system is not properly functional, the ditch blocked and covered by debris and eroded soil. As a result of this water will force to overflow on the pavement and infiltrate beneath of pavement structure. As shown from figure 4.5 the cross section and grading of the ditch cannot be easily collect surface runoff and safely drain out.

a) Ditch covered by eroded soil b) Ditch covered by plants

Figure 4.5: Ditch condition

4.2.2. Drainage Condition According to Cross-Section Capacity

The ditch was proposed to collect water from shoulder and side slope to drain out by a bed slope of 1%. The road has one shoulder at the right side with an average slope of 1% toward the ditch. Because of improper functionality of the ditch, the cross section of the ditch is not enough to drain the runoff safely.

The cross section, dimension of drainage and shoulder are described in table 4.10 and in figure 4.6. Surface runoff flow from the shoulder are directing toward the right side ditch as shown in figure 4.6.

Table 4.10: Summary of drainage cross section

No.	Description	Length	Average Width	Average height
1	Drainage	177m	1.8m	1.3m
2	Shoulder	275m	2.9m	

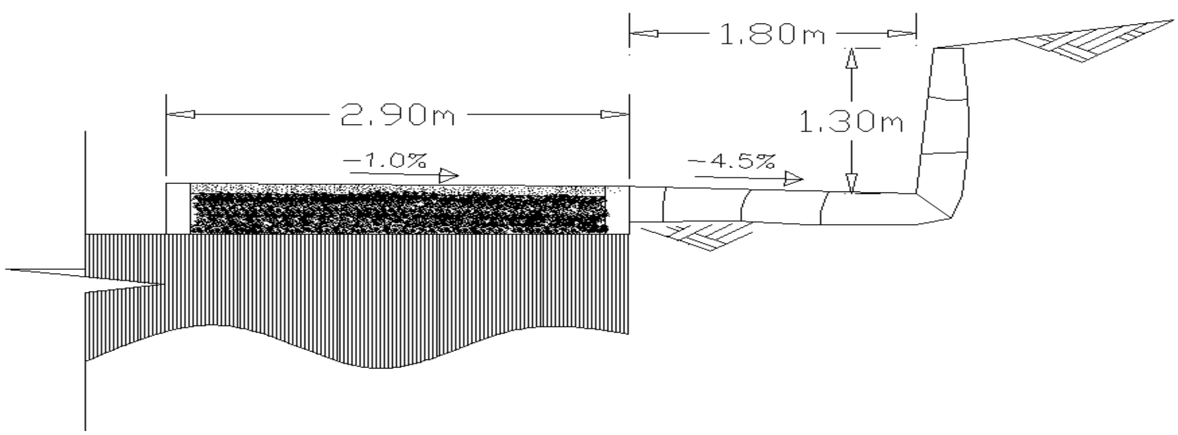


Figure 4.6: Typical Drainage and shoulders cross section at 0+094

4.2.3. Condition of Ditch

- Threshold Condition

The data recorded by the station interval by taking representative average thickness and the average area calculated by measuring the lateral spread along cross section of the ditch and multiplied by the station interval as shown in table 4.11. The average thickness of threshold covers 6.5cm and 269.3m^2 total areas. These would result blocking of ditch and make surface runoff to over flow on a shoulder and pavement.

Table 4.11: Summary of extent of threshold coverage

No.	Station(km)	Threshold coverage average thickness	Average area of Threshold coverage
1	0+061 - 0+120	7cm	88.5m^2
2	0+120 - 0+200	5cm	120.0m^2
3	0+200 - 0+0+238	8cm	60.8m^2

- Outlet Condition

The outlet of the ditch is located at 0+238 as shown in table 4.12 which is circular concrete ditch about 67% the section has clearly opened. It were proposed to drain out the collected runoff from opened triangular paved ditch, but the area of out let is less than the wetted triangular ditch these shows incapability of drainage outlet.

Table 4.12: Summary of outlet condition

No.	Description	Location(km)	Diameter	Height of Opened Section
1	Outlet	0+238	30cm	20cm

CHAPTER FIVE

DATA COLLECTION AND ANALYSIS LABORATORY TESTS

Introduction

Method of subgrade soil identification, soil sampling and laboratory tests are discussed in this chapter. Samples were collected and submitted to Transport Design Construction SC. and AR CON design and build for laboratory work.

5.1. Subgrade Soil Investigation

Subgrade soil investigations are used to know the type of soil, the property of soil type that affects the pavement structure [4]. These have done using visual inspection and by conducting laboratory tests [7].

5.1.1. Visual Inspection of Subgrade Soil

The visual inspection of soil indicates that; the color of soil is black and has high stickiness property in hand when it mixes with water. Therefore as per visual inspection the soil has a property of expansive black cotton soil.

5.1.2. Subgrade Soil Sampling

Sub grade soil data is classified in two main parts these are;

Primary data: The sub grade soil sample pit were taken from different places along the side nearby roadway sides by considering the severity of the road to investigate the engineering properties of the sub grade soils that were identified during site visits with three representative test pits.

The significance of sub grade soil sampling is to carry out assessment on the nature of sub grade soil characteristics along the study area and to identify contribution of subgrade for the observed road defects. Depth of sampling had taken based on ERA site investigation manual summarized as given in Table 5.1. Three sample pits had taken in fill material and sub grade from 0+034 to 0+125 km station interval and the average sample depth 1.5m.

Table 5.1: Summary of representative sample condition

No.	Station(km)	Depth(m)	Sample type
1	0+034 LHS	1.6	Fill material
2	0+054 RHS	1.4	Sub grade material
3	0+125 RHS	1.5	Sub grade material

Secondary data: From the nearby Ethiopian Water Technology Institute (EWTI) three samples had taken. The soils samples analyzed for grain size analysis and Atterberg limit at depth of 2.4m were conducted for subgrade soil for a purpose of laboratory building construction. These tests help to know the soil property of research surrounding which is selected because it has similar soil property with pavement sub grade.

5.2. Laboratory Tests for Subgrade Soil

Introduction

The characteristic of materials underlying the pavement structure can have a significant influence on pavement performance [4]. The critical question of any pavement design regarding to material is the characterizations of the material upon which the pavement structure will be constructed and selection of material for components of pavement structure that can able to withstand the possible distress in tolerable manner.

For characterization of sub grade material and pavement structure material the following laboratory tests are conducted: Specific gravity, Grain size Analysis, Atterberg limits (liquid limit, plastic limit and plasticity index), Compaction test (modified proctor tests), Natural moisture content, CBR value and Swelling pressure were conducted.

5.2.1. Natural Moisture Content

The fine-grained soil largely depends on its water holding capacity of soil which will have expansive nature as the natural moisture content of soil increased. The test is conducted in accordance with AASHTO T265. The natural moisture content obtained from undisturbed which is taken by Shelby tube for subgrade soil because it is tried samples range in between 20.86 % to 40% as shown in table 5.2.

Table 5.2: Summary of Natural Moisture Content

No	Station(km)	Moisture Content, %
1	0+054 RHS	33.63
2	0+125 RHS	30.52
3	0+034 LHS	20.86

5.2.2. Specific Gravity

The specific gravity of a soil is used in the phase relationship of air, water and solids in a given volume of the soil and increase as the material goes from course to fine grained soils [3, 12]. The sample has taken disturbed and the test is conducted in accordance with AASHTO T100-93 testing procedure. The average specific gravity of the soil of the research was 2.70.

5.2.3. Grain Size Distribution

Sieve analysis was carried out to determine the grain size distribution of sub-grade soil and fill material and used for soil classification. Disturbed soil samples were prepared and Wet sieve analysis was performed to determine soil classification as per AASHTO T 088 soil classification system by providing the percentage of different grain sizes distribution contained in a soil mass. Soil more than 35% pass in sieve no. 200 are classified as silty-clay materials and Soil less than 35% pass in sieve no. 200 are classified as Granular materials.

Table 5.3: Summary of Grain size analysis

Sieve size(mm)	% passed					
	Km 0+054RHS	Km 0+125RHS	Km 0+034 LHS	Data from EWTI at RHS at 2.4m depth		
				BH 1	BH 2	BH 3
63.5	100	100	100	98	98	98
50.0	100	100	98	95.5	95	95
37.5	100	100	71	94	94.5	94
25.0	100	100	63	93.5	94	93
19.0	100	100	57	93	93.5	93.5
12.5	100	100	53	61	74	68
9.5	100	100	45	61.5	71.5	64
4.75	100	100	38	58	71	64.5
2.00	100	100	31	58.5	68	61
0.85	90	93	29	55	68.5	61.5
0.425	88	89	22	51	61	54
0.075				44	54	47

5.2.4. Atterberg Limits

Performed to classify a fine-grained soil according to the AASHTO T 089 & T 090 Soil Classification system by determining the moisture content of the plastic limit where the soil changes from a semi-solid to a plastic (flexible) state, liquid limit where the soil changes from a plastic to a viscous fluid state and shrinkage limits where the soil volume will not reduce further if the moisture content is reduced of a fine grained soil. The sample was prepared disturbed soil sample and the plasticity index of test result ranges between 22 to 34.

$$\text{Plasticity Index (PI)} = \text{Liquid Limit (LL)} - \text{Plastic Limit (PL)}$$

Table 5.4: Summary of Atterberg Limits

Atterberg Limits	**Km 0+054RHS**	**Km 0+125RHS**	**Km 0+034 LHS**	**Data from EWTI at RHS at 2.4m depth**		
				BH 1	**BH 2**	**BH 3**
LL	56.99	57.15	43.23	48.62	45.51	53.3
PL	23.36	26.63	21.15	22.71	18.18	24.23
PI	33.63	30.52	22.08	25.91	27.33	29.07

5.2.5. Compaction Test

This laboratory test is performed to determine the relationship between the moisture content and the dry density of a soil for a specified proctor compaction effort. According to the AASHTO T 134 the compaction effort is the amount of mechanical energy that is applied to the soil mass.

The Standard Proctor Test provide relationship between water content and dry density and the maximum moisture content at which maximum dry density is attend obtained from the relationship provided by the test. The sample was prepared disturbed soil sample and the MDD result ranges between 1.30 to 1.70 gm/cc which is input for CBR value computation.

Table 5.5: Summary of Compaction Test

Atterberg Limits	**Km 0+054RHS**	**Km 0+125RHS**	**Km 0+034 LHS**	**Data from EWTI at RHS at 2.4m depth**		
				BH 1	**BH 2**	**BH 3**
MDD (gm/cc)	1.489	1.405	1.63	1.403	1.38	1.404
OMC (%)	25.60	22.44	21.5	21.75	25.6	24.87

5.2.6. California Bearing Ratio (CBR) Tests

The CBR is the most widely applicable methods for determining the sub grade and pavement structures strength study according to AASHTO T 193. The CBR value for a soil is a combination of proctor compaction values. Three points CBR tests were carried out with 4 days soaking helped to determine the sub-grade soils condition at the worst moisture conditions. The sample was prepared disturbed soil sample and the CBR result ranges between 1.50 to 2.00 at 95% MDD.

Table 5.6: Sub grade CBR value of station 0+054

No. of blows	Dry density(gm/cc)	MDD (gm/cc)	95% MDD (gm/cc)	CBR (%)	CBR swell (%)	CBR at 95% MDD
10	1.39	1.4885	1.414	1.66	1.86	1.85
30	1.45			2.17	1.66	
65	1.54			2.56	1.48	

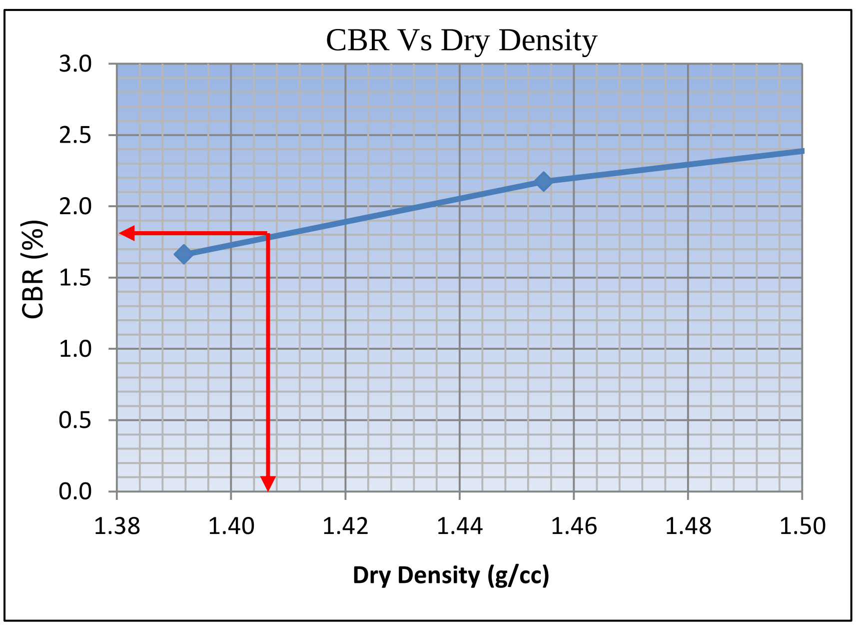


Figure 5.1: CBR test result of station 0+054

Table 5.7: Sub grade CBR value of station 0+125

No. of blows	Dry density(gm/cc)	MDD (gm/cc)	95% MDD (gm/cc)	CBR (%)	CBR swell (%)	CBR at 95% MDD
10	1.14	1.41	1.33	1.53	2.06	1.76
30	1.23			1.66	1.82	
65	1.37			1.79	1.76	

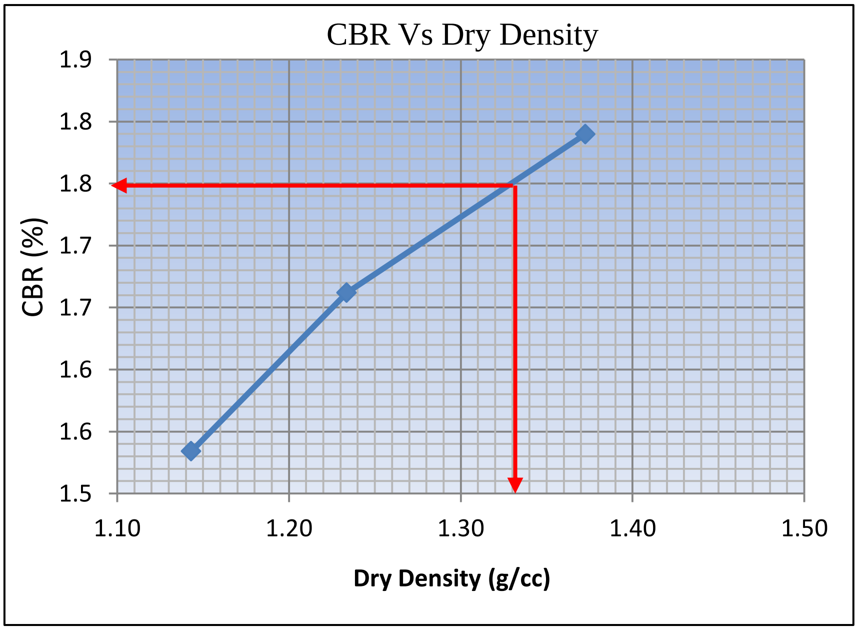


Figure 5.2: CBR test result of station 0+125

5.2.7. CBR Swell Values of the Subgrade Soils

The swelling potential tests conducted during CBR soaking for 4 days can also be used to estimate the expansive nature of the subgrade soils. The swelling potential is defined as the percentage swell of a laterally confined sample which has been compacted by compaction results of MDD at OMC which is extracted from CBR test result swelling values ranges between 1.3 to 2.1 as shown in table 5.8.

Table 5.8: Sub grade CBR swelling value

No	Station(km)	No. of blow	CBR swell in %	CBR swell
1	0+054RHS	10	1.86	1.85
		30	1.66	
		65	1.48	
2	0+125RHS	10	2.06	1.76
		30	1.82	
		65	1.76	

5.2.8. Prediction of Swelling Pressure of the Subgrade Soils

Swelling Pressure value suggested by different literatures and summarized in a table 5.9.

- Method of Seed at al., (1962) defines the swelling potential by plasticity index and constant coefficient.

Table 5.9: Prediction of swelling pressure from Equation 2.1

No	Station(km)		Plasticity Index	Swelling potential in %
1	0+054RHS		33.63	9.97
2	0+125RHS		30.52	7.89
3	0+034 LHS		22	3.60
4	Data from EWTI at RHS at 2.4m depth	BH1	25.91	5.33
5		BH2	27.33	6.59
6		BH3	29.07	7.03

- Method of Skempton describes the degree of activity potential and plasticity index.

Table 5.10: Prediction of Activity potential from Equation 2.2

No	Station(km)		Plasticity Index	Activity potential in %
1	0+054 RHS		33.63	0.387
2	0+125 RHS		30.52	0.347
3	0+034 LHS		22	1
4	Data from EWTI at RHS at	BH1	25.91	0.443
5		BH2	27.33	0.402

6	2.4m depth	BH3	29.07	0.477

- Method of Anderson et al [1] define the plasticity index and swelling potential.

Table 5.11: Prediction of swelling pressure from Equation 2.3

No	Station(km)		Plasticity Index	Swelling potential in %
1	0+054RHS		33.63	4.615
2	0+125RHS		30.52	3.89
3	0+034 LHS		22	1.94
4	Data from EWTI at RHS at 2.4m depth	BH1	25.91	2.84
5		BH2	27.33	3.17
6		BH3	29.07	3.57

5.2.9. Evaluation of Sub Base and Sub Grade Soil

Evaluation of sub base / sub grade

The values of D15 and D85 for different stations are shown in table 5.12.

Table 5.12: Summary of Ratio of D15 and D85

No	Location	D15	D85	Ratio of D15/D85
1	Km 0+034 LHS	0.24		
2	Km 0+054 RHS		0.03	8
3	Km 0+125 RHS		0.01	24
4	BH1		0.06	4
5	BH2		0.05	4.8
6	BH3		0.055	4.36

At Km 0+054 RHS and Km 0+125 RHS the ratio of D15/D85 is greater than 5 and BH1, BH2 and BH3 is less than 5.

CHAPTER SIX

RESULTS AND DISCUSSIONS

INTRODUCTION

This chapter mainly deals interpretation and discussion on collected data and laboratory test results which investigated earlier. Classification of soil, subgrade strength class, swelling effect, drainage condition, design requirement of pavement subgrade are included to determine causes of pavement distresses.

6.1. Discussion on Test Results

6.1.1. Soil Classification Based on AASHTO Classification System

i) Grain Size Distribution

Based on the Atterberg limit and Grain size distribution test results soil classification are made based on AASHTO soil classification system as shown in table 6.1 and The minimum percent pass sieve no. 200 for the subgrade soil under the research is 22 %. The subgrade soils are groups in clayey soil with poor subgrade causes considerable volume change upon moisture fluctuation.

Table 6.1: AASHTO Soil classification

No	Sample station(km)		AASHTO classification	Soil type	Rating
1	0+054RHS		A-7-6	Clayey soil	Poor
2	0+125RHS		A-7-6	Clayey soil	Poor
3	0+034 LHS fill		A-2-7	Silty-clayey gravel sand	Good
4	Data from EWTI at RHS at 2.4m depth	BH1	A-7-6	Clayey soil	Poor
5		BH2	A-7-6	Clayey soil	Poor
6		BH3	A-7-6	Clayey soil	Poor

ii) Atterberg Limits

Atterberg Limits (Liquid Limit, Plastic Limit) test result is required to classify the sub grade soils according to AASHTO soil classification system. Measured liquid limit was found in the range of 45% to 58% and plasticity index in the range of 25% to 34%. The plasticity index result is also input to determine swelling potential.

6.1.2. California Bearing Ratio (CBR) tests

California Bearing Ratio (CBR) test measure the structural strength capacity of subgrade without any structural damage in the worst condition. From CBR test result of the subgrade soil of the research is between 1% - 2% conducted for subgrade soil CBR at optimum moisture content and laboratory test result and according to ERA pavement design manual the subgrade class is S2. According to ERA design manual subgrade class with CBR less than 3 needs special treatment cannot support structures constructed.

Table 6.2: Summary of CBR test value and sub grade classification

No	Station(km)	CBR at 95% MDD	Subgrade strength class	Liquid Limit	Value as Subgrade
1	0+054 RHS	1.85	S2	56.99	Poor
2	0+125 RHS	1.76	S2	57.15	Poor

6.1.3. CBR Swells Value

The CBR swelling value indicates the minimum and maximum swelling pressures are 1.85% and 1.76% respectively.

6.1.4. Swelling Pressure

Prediction of swelling pressure using different methodology is done. The result of that potential expansion of a soil indicates high potential expansion results as shown in the table 6.3.

Table 6.3: Prediction of swelling pressure by method of Seed at al., (1962) classification

No	Station(km)		Swelling potential in %	Expansion potential
1	0+054RHS		9.97	High
2	0+125RHS		7.89	High
3	0+034 LHS embankment fill		3.60	Medium
4	Data from EWTI at RHS at 2.4m depth	BH1	5.33	High
5		BH2	6.59	High
6		BH3	7.03	High

Table 6.4: Prediction of activity potential by method of Skempton classification

No	Station(km)		Activity potential in %	Activity
1	0+054RHS		0.387	Inactivity
2	0+125RHS		0.347	Inactivity
3	0+034 LHS embankment fill		1	Normal
4	Data from EWTI at RHS at 2.4m depth	BH1	0.443	Inactivity
5		BH2	0.402	Inactivity
6		BH3	0.477	Inactivity

Table 6.5: Prediction of swelling potential According to Method of Anderson et al [1]

No.	Station(km)		Plasticity index	Swelling potential %	Degree of expansion
1	0+054RHS		33.63	4.615	High
2	0+125RHS		30.52	3.89	Medium
3	0+034 LHS embankment fill		22	1.94	Medium
4	Data from EWTI at RHS at 2.4m depth	BH1	25.91	2.84	Medium
5		BH2	27.33	3.17	Medium
6		BH3	29.07	3.57	Medium

6.2. Identification of Cause of Problems

The pavement condition survey indicates different road distress observed on rigid pavement. Some factors may result those defects such as; Traffic load condition, pavement design, sub grade material property, drainage condition, pavement material property etc.

Basically regarding to this research pavement distress causes evaluated based on sub grade material property and drainage condition and pavement sub grade design criteria.

6.2.1. Based on Sub Grade Material Property and Drainage Condition

From laboratory test results of sub grade materials is clayey soil the property of sub grade has low structural capacity, high shrinkage and swelling potential. Form drainage condition survey result blocking of drainage outlet accumulation of threshold and silt are measured and observed. The surface runoff will forced to over flow on the pavement structure and infiltrate to the pavement beneath and subgrade. This would result change on the property of sub grade nature and create crack, settlement and different structural damage in variable moisture content

From evaluation of sub base and sub grade soil results, the ratio is greater than 5 for primary test result and less than 5 for secondary test result as per ERA standard so, it shows the subgrade soil need to be excavated and removed up to 2.5m referring to secondary test result borehole depth and replaced by suitable material, the ratio greater than 5 is impervious media should be placed between sub grade and sub base.

6.2.2. Based on Pavement Subgrade Design Criteria

According to ERA design manual, if the CBR of the subgrade value is 15% or less, capping layer is required only and the thickness of layer defined by the manual. The sub base layer is required when the subgrade material doesn’t comply with the requirement for a sub base (CBR is less than 30%) but it is almost always used to facilitate the obtaining of surface levels with the tolerances required. Generally, the thickness of the sub base provided will be a constant 15 cm and can be stabilized. For subgrade CBR values inferior to 2%, the subgrade material needs to be treated either by replacement or in-situ stabilization.

The CBR test value of research pavement subgrade range in between 1% - 2% shows the subgrade material needs treatment by different method of stabilization.

According to pavement condition index result the value is 32.1 categorized as very poor rating, it shows that should be treated rapidly before further destructions are followed.

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATION

7.1 Conclusion

This research, the following conclusion has been drawn.

- The research focused on influence of subgrade soil on selected rigid pavement which shows different road distresses on the pavement. The rigid pavements were considered solution for repetitive pavement distress constructed on expansive soil.

- Different literatures compiled to understand black cotton soil, soil sampling, rigid pavement review, road distress identification, drainage condition assessment and previous researches.

- The research area is located at Akaki Kality sub city. The surface runoff forced to remain on the pavement because of absence of side drain and flatness of the pavement. The climate condition and drainage condition helps for development of expansive soil.

- The road condition assessment classified based on pavement distress such as; Corner Breaks, Joint Seal Condition, Spalling, Cracking and Lane-to-Shoulder Separation. The drainage condition evaluated according to topography, according to cross-section capacity and condition of ditch.

- The pavement distresses corner breaks, joint seal damage, cracking and lane-to-shoulder separation facilitate for easily percolation surface runoff. These would result further deterioration of pavement concrete and increase the swelling and shrinkage potential of sub grade.

- The pavement condition index classified as very poor rating, it is also causes for pavement concrete failure, reduction of serviceability of the road and failure of sub grade.

- The subgrade soil of the research area is classified as A-7-6 clayey and A-2-7 Silty-clayey gravel sand soil for fill material according to AASHTO classification system, Furthermore, Natural Moisture Content, Specific Gravity, Grain Size Distribution, Atterberg limits, Compaction Test and California Bearing Ratio (CBR) Tests results of the soil shows that ,the subgrade soil has a very low bearing capacity and high swell pressure which makes it unsuitable subgrade soil to construct structures on it without any proper treatment measures.

- The plasticity index of laboratory test results of sub grade and fill materials ranges in between 22% to 35%, according to ERA standard the sub grade and fill materials should be less than 12%. This would be one factor for measured and recorded pavement distress.

- The CBR laboratory test results of sub grade soil ranges in between 1.5% to 2%, according to ERA standard the CBR value categorized as S1 the sub grade class. Therefore subgrade CBR values inferior to 2%, the subgrade material needs to be treated. The predicting swelling potential results of subgrade soil and fill material shows high swelling potential which is unsuitable and problematic soil.

- The evaluation of sub base and sub grade soil result is greater than 5 on primary data, according to ERA standard the value should be less than 5 therefore treatment measure should be taken.

- The inadequacy of cross section of ditch made the surface runoff to flow on the pavement and because of lack of side ditch beneath a pavement the water accumulated on a pavement this would made the water infiltrate to the subgrade trough time.

7.2 Recommendation

- By considering main factors of material property such as; swelling potential, the CBR value, the plasticity index of sub grade soil, it is important to determine depth and type of replacement material.

- Adequate side drain ditch should be provided at a beneath of pavement to prevent possible infiltration effect of surface runoff on a pavement down to the sub-grade and ditch should be preserved from leakage and kept from moist during road bed preparation and pipe installation.

- The defected concrete pavement should be removed and properly designed and treated as pre ERA design manual.

- Using different stabilization methodology according to ERA 2002 manual the unsuitable sub-grade soils and fill material parts need to be well treated until the problematic subgrade zone becomes stable, but it should not be limited by the recommended excavation depth to 600 mm and replace it with a non-expansive soil having a minimum CBR of 5%, 2% swell because of problematic property of subgrade and fill material.

- Evaluation of sub base and sub grade soil result shows the sub base material thickness placing should be up to the stable zone of sub grade and there should be a filter layer between sub base and sub grade.

- Using different expansive soil stabilization techniques such as chemical or physical methods of stabilization treat the subgrade soil.

- Before deciding rigid pavement as a final maintenance option knowing the property and strength of sub grade soil and fill material, drainage condition, effect of sub surface water flow on are important factor to increase service time of the road.

- Trough out drainage extent from station 0+061 to 0+238 the sliding soil from side slope should be well preserved by the following option; excavating soil from the wall toy of institute to top of ditch, making stepped excavation of the slope and using gabion reduce the possible sliding effect to prevent accumulation of silts and debris on a ditch.

- The out let of the ditch should be redesign according to ERA 2002 manual to provide sufficient drainage out let to drain out the collected runoff from surrounding safely.

- This research inspired to the need of rigid pavement is not direct solution for serious flexible pavement damage ground improvement technique must be arranged.

- Since rigid pavement is a new practice in Ethiopia, there is no previous study which was made on the sub grade evaluation in rigid pavement, so further researches would require based on topography, environment, traffic condition, pavement construction materials and clay mineral compositions of the soil before implementing these results or findings to other road project, but it shall be considered as indicative.

LIST OF REFERENCES

1. North Carolina Department of Transportation (NCDoT) Pavement Management Unit (2008), Pavement Condition Survey, Unpublished technical report, 6 pp.
2. Ethiopian Road Authority (ERA) manual (2002), Drainage Design Manual, Unpublished technical report, Addis Ababa, Ethiopia.6 pp.
3. Arora K.R. (2003), Soil and Foundation Engineering, Standard Publisher Distribution, New Delhi, India. 13 pp, 439 pp.
4. Muni Budhu (2000), Soil Mechanics and Foundations, John Wiley & Sons, Inc. New York. 6 pp.
5. Ethiopian Road Authority (ERA) manual (2002), Site Investigation Manual, Unpublished technical report, Addis Ababa, Ethiopia. 9 pp.
6. Murthy V.N.S. (2007), Principle and Practices of Soil Mechanics and Foundation Engineering, Marcel Dekker, Inc., New York. 800 pp.
7. Alemayew Tefera and Mesfin Leykun (1999). Soil mechanics, Addis Ababa printing press 5,436 pp.
8. Florida Department of Transportation (2015). Rigid Pavement Condition Survey, Unpublished technical report, Florida USA 5, 436pp.
9. Ethiopian Road Authority (ERA) manual (2002), unbound pavement material, Unpublished technical report, Addis Ababa, Ethiopia. 7 pp.
10. North Carolina Department of Transportation (2002). Maintenance Condition Assessment Program Manual, Unpublished technical report, USA. 10pp.
11. Department of transportation federal highway administration US (2003). Distress Identification Manual for Long Term Pavement Performance Program, Unpublished technical report, USA.33pp.
12. Krishna Reddy, UIC (2004). Engineering Properties of Soils Based on Laboratory Testing, Unpublished technical report, 3pp.
13. Norbert Delatte (2008). Concrete Pavement Design Construction and Performance, Unpublished technical report, 25,65pp.

14. Opus International Consultants Limited (2016).Pavement Surface Condition Rating Manual, Unpublished technical report, 7pp.
15. Ministry of Bangladesh Roads and Highways Department (2001). Road Condition Survey Manual, Unpublished technical report, 12,18pp.
16. Florida Department of Transportation Pavement Management Office (2009). Rigid Pavement Design Manual, Unpublished technical report, Florida, USA. 125pp.
17. Federal Highway Administration of USA (2009). Pavement Distress Identification Manual, Unpublished technical report, 1pp.
18. Florida Department of Transportation (FDOT) (2017). Rigid Pavement Condition Survey Handbook, Unpublished technical report, Florida, USA. 3pp.
19. Ethiopian Road Authority (ERA) manual (2002). Rigid Pavement Design Manual, Unpublished technical report, Addis Ababa, Ethiopia.3pp.
20. New University of Lisbon (2014). Rigid Pavements Distress Pavement Condition Index Evaluation, Unpublished technical report, 44pp
21. Melik Yunus (2015).Performance of road constructed on black cotton subgrade soil with respect to replacement materials type and replacement depth in a case study of on Modjo Edjere road. Unpublished MSc Thesis, Addis Ababa University, Addis Ababa, Ethiopia.
22. Fiker Alebachew (2005).Pavement distress on Addis Ababa city Arterial roads, causes and maintenance options. Unpublished MSc Thesis, Addis Ababa University, Addis Ababa, Ethiopia.
23. Nibret Chane (2011). Geotechnical characterization of subgrade materials for pavement construction a case Study on Aposto – Wondo – Negele Road Upgrading Project Unpublished MSc Thesis, Addis Ababa University, Addis Ababa, Ethiopia.
24. Habtamu Solomon (2011). Chemical Stabilization of Expansive subgrade soil performance evaluation on selected road section in northern Addis Ababa. Unpublished MSc Thesis, Addis Ababa University, Addis Ababa, Ethiopia.
25. Eyrusalem Abdulkader (2015). Settlement Analysis on Expansive Soils in Bole Sub-City. Unpublished MSc Thesis, Addis Ababa University, Addis Ababa, Ethiopia, 10pp.
26. North Carolina Department of Transportation (NCDT) (2011). Digital imagery distress evaluation handbook, Unpublished technical report, North Carolina USA.33pp.

27. Gary L. Brhel(2007). Pavement Condition Survey Manual, Unpublished technical report, 20pp.
28. Florida Department of Transportation (2014). Drainage Handbook Storm Drains, Unpublished technical report, Florida USA.15pp.
29. Tom Tidwell Chief (2010). Watershed Condition Classification Technical Guide, Unpublished technical report, 4pp.
30. North Carolina Department of Transportation (2010). Maintenance Condition Assessment Program Manual, Unpublished technical report, North Carolina USA. 21pp.
31. Norbert Delatte (2005). Concrete Pavement Design, Unpublished technical report, 15pp.
32. Texas Transportation Institute Team, (2012). Subbase and Subgrade Performance Investigation and Design Guidelines for Concrete Pavement, Unpublished technical report, Texas USA. 15pp.
33. Ipwea-Nams.Au, (2009). Condition Assessment and Asset Performance Guidelines, Unpublished technical report, 12pp.
34. Nii Attoh-Okine & Offei Adarkwa(2013). Pavement Condition Surveys– Overview of Current Practices, Unpublished technical report, 23pp.
35. Martin Rogers (2003). Highway Engineering Department of Civil and Structural Engineering, Blackwell Publishing Ltd, 192pp.
36. Malcomcopson, Peter kenderick, Steve Beresford and Paul McCormick (2004). Road Work Theory and Practice, Unpublished technical report, 47,102pp.
37. Bell F.G. (2007).Engineering Geology, Butterworth-Heinemann, London UK. 70pp.
38. Army Corps of Engineers Engineering and Design (2001) U.S. Geotechnical Investigations Department of U.S Army, Unpublished technical report.
39. Department of the Interior Bureau of Reclamation (1998) U.S. Engineering Geology Field Manual Volume 1&2, Unpublished technical report.
40. Yang H. Huang (2004). Pavement Analysis and Design, Unpublished technical report.

APPENDIX

Appendix 1

Relation between swelling potential and plasticity index, I_p

Plasticity index lp (%)	Swelling potential
0-15	Low
10-35	Medium
20-55	High
35 and above	Very high

Appendix 2

Relation between swelling potential, shrinkage limits, and linear shrinkage

Shrinkage limit %	Linear shrinkage %	Degree of expansion
<10	>8	Critical
10-12	5-8	Marginal
>12	0-5	Non-critical

Appendix 3

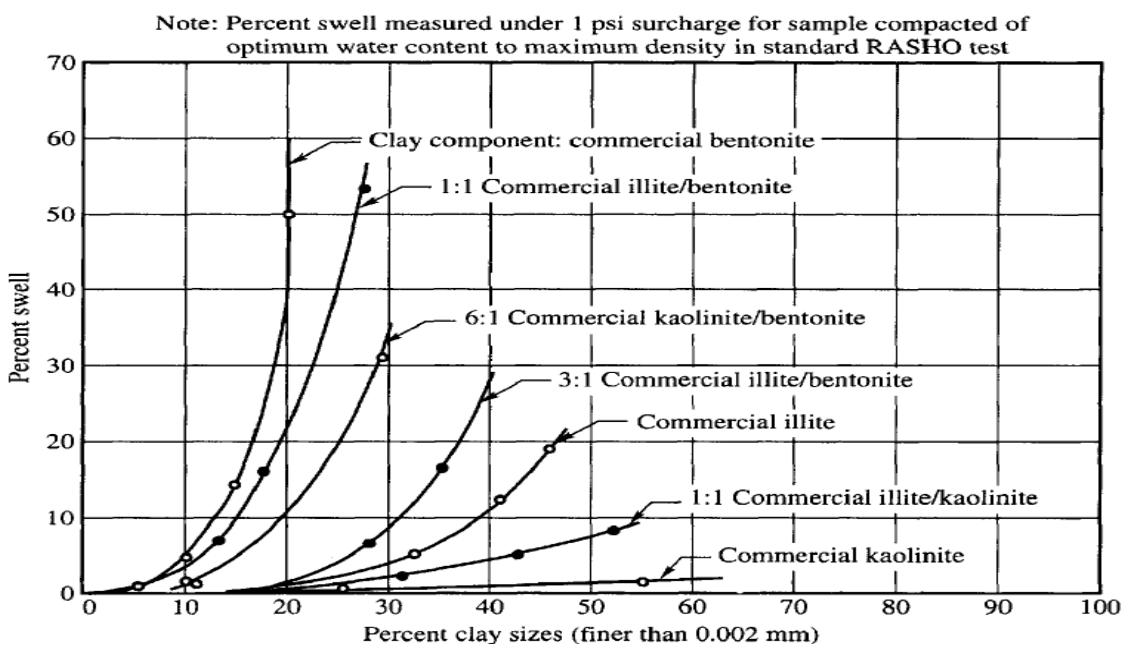


Figure 18.10 Relationship between percentage of swell and percentage of clay sizes for experimental soils (after Seed et al., 1962)

Appendix 4

Swelling Potential Classification

Swelling pressure	Expansiveness
S_p<1.5	Low
1.5<S_p<5	Medium
5<S_p<15	High
S_p>25	Very high

Appendix 5

Degree of colloidal activity

Degree of activity	Activity
Inactivity	<0.75
Normal	0.75-1.25
Active	>1.25

Appendix 6

Relationship between plasticity index and swelling potential

Degree of expansion	Plasticity index	Swelling potential
Low	20	1.5
Medium	20-31	1.5-4.0
High	31-39	4.0-6.0
Very high	39	6.0

Appendix 7

Summary of Severity Levels

Severity Level	Damage extent in length	Corner break extent(in pcs)
Low	<=1/4	1pcs
High	>1/4	>2pcs

Appendix 8

Summary of Severity Levels

Severity Level	**Damage extent in percentage**
Low	<=10%
Medium	>10% and <=50%
High	>50%

Appendix 9

Summary of Severity Levels

Severity Level	**Spalls extent width**
Low	<=3 in, no loss of material or patching
Medium	>3in and <=6in, loss of material. May be patched
High	>6in, loss of material. May be patched

Appendix 10

Summary of Severity Levels

Severity Level	**Width**	**Length**
Low	<=6mm	<=32.8mm
Medium	>6mm and <=19mm	<=150mm
High	>19mm	>150mm

Appendix 11

Summary of Severity Levels

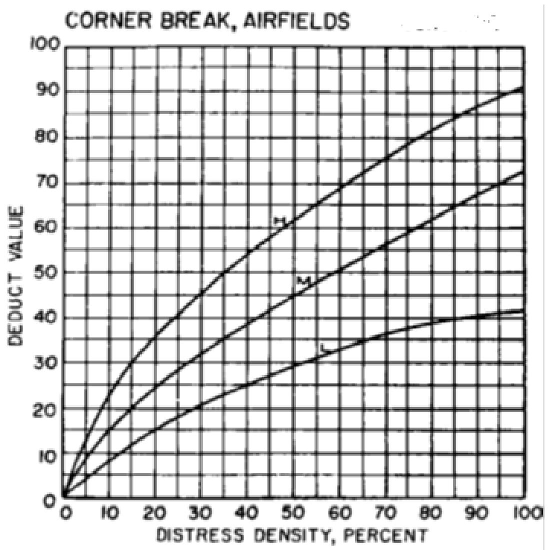
Severity Level	**Width**
Low	<6mm
Medium	>6mm and <=19mm
High	>19mm

Appendix 12

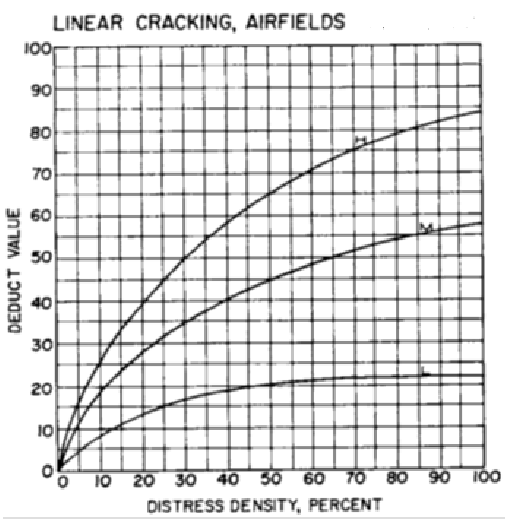
Summary of Severity Levels

Severity Level	Width
Low	<6mm
Medium	>6mm and <=19mm
High	>19mm

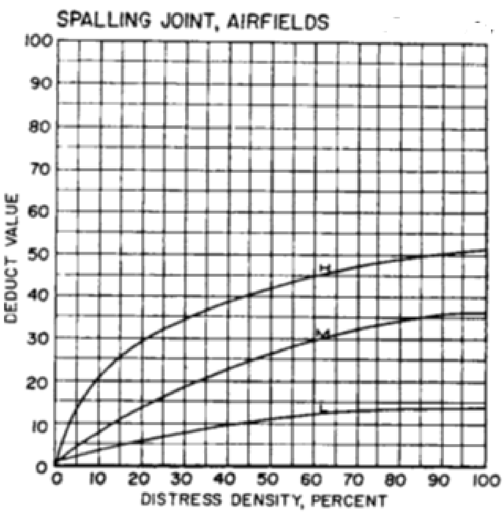
Appendix 13



Appendix 14



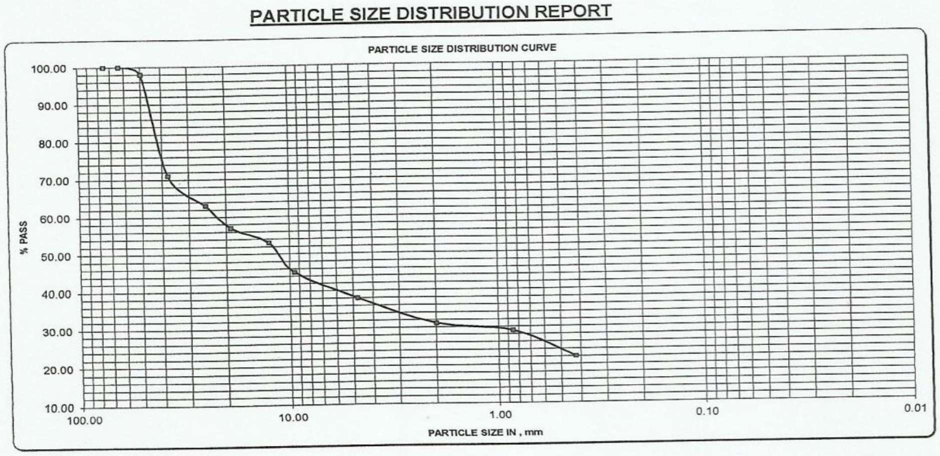
Appendix 15


SPALLING JOINT, AIRFIELDS
DEDUCT VALUE
DISTRESS DENSITY, PERCENT
H
M
L
0
10
20
30
40
50
60
70
80
90
100

Appendix 16

Test results

PARTICLE SIZE DISTRIBUTION REPORT



SIEVE SIZE (MM.)	% PASSED
63.500	100
50.000	98
37.500	71
25.000	63
19.000	57
12.500	53
9.500	45
4.750	38
2.000	31
0.850	29
0.425	22

Soil Description	
Low plastic SILT	
Atterberg Limit	
LL	43
PI	22
Classification	
USCS :-	
AASHTO:-	A - 2 - 7

% COBBLE	% GRAVEL	% SAND	% FINE
-	62	16	22

REPORTED BY

APPROVED BY

AR♦CON Design-Build plc.

GEOTECHNICAL ENGINEERING SERVICE

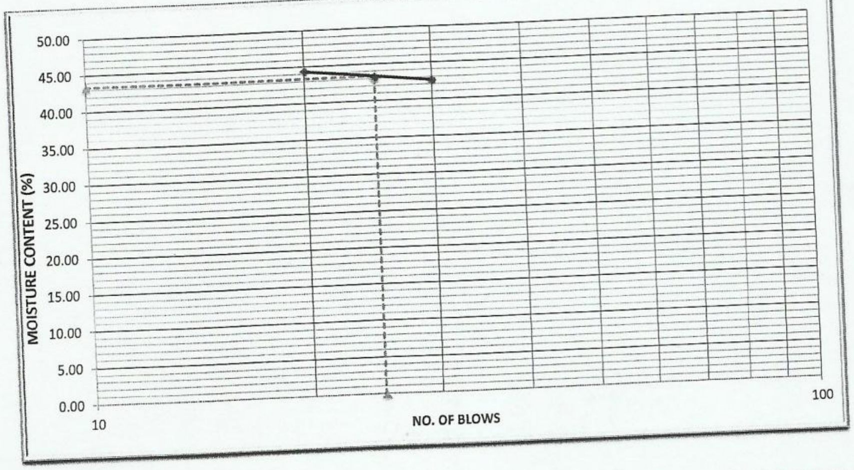
P.O.Box 110246, Addis Ababa Ethiopia

Tel. +251 11 860 36 99, +251 11 860 37 83/84, Fax: +251 860 36 99

E-mail: ar-con@ethionet.et

CLIENT	:	Michael Ababu
PROJECT	:	Kality Ring Road Rigid Pavement
TEST OBJECT	:	Disturbed soil
LAB. NO	:	36660/2017
SAMPLE SOURCE	:	Fill material(Sample - 01)
SAMPLE DEPTH(m)	:	1.60
TEST FOR	:	Sieve Analysis(AASHTO T- 88)
REPORTED ON	:	03/05/2017

LIQUID AND PLASTIC LIMITS TEST REPORT



	LIQUID LIMIT			PLASTIC LIMIT	
No. Blows	30	25	20		
Wt. wet soil (g.)	17.89	17.89	17.92	2.98	2.69
Wt. dry soil (g.)	12.54	12.49	12.41	2.46	2.22
Moisture content (%)	42.66	43.23	44.40	21.14	21.17
				AV. PL (%)	21.2

Liquid Limit LL(%)	Plastic Limit PL(%)	Plasticity Index PI	WET SEIVE ANALYSIS, % PASS 2mm	0.425mm	0.075mm
43.23	21.15	22.08	31.00	22.00	0.00

REPORTED BY

APPROVED BY

ሰለሞን ጥበቡ ቸኮል
የአፈርና የኮንስትራክሽን
ቁሳቁሶች ላቦራቶሪ ኃላፊ
Solomon Tibebu Chekol
Soil & Construction Materials
Laboratory Head

AR♦CON Design-Build plc.

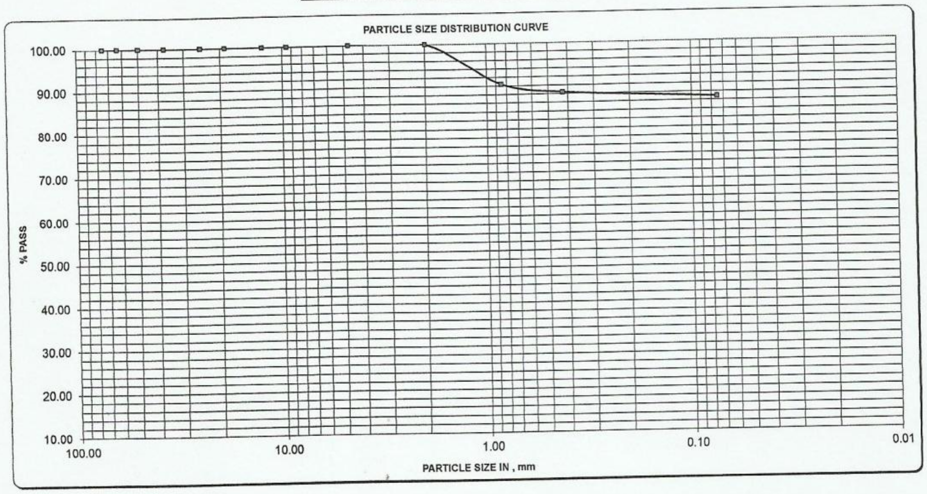
GEOTECHNICAL ENGINEERING SERVICE

P.O.Box 110246, Addis Ababa Ethiopia

Tel., +251 11 860 36 99, +251 11 860 37 83/84, Fax: +251 860 36 99

CLIENT	:	Michael Ababu
PROJECT	:	Kality Ring Road Rigid Pavement
TEST OBJECT	:	Disturbed soil
LAB. NO	:	36661/2017
SAMPLE SOURCE	:	Fill material(Sample - 01)
SAMPLE DEPTH(m)	:	1.60
TEST FOR	:	Atterberg Limit
REPORTED ON	:	03/05/2017

PARTICLE SIZE DISTRIBUTION REPORT



SIEVE SIZE (MM.)	% PASSED
63.500	100
50.000	100
37.500	100
25.000	100
19.000	100
12.500	100
9.500	100
4.750	100
2.000	100
0.850	90
0.425	88

Soil Description
Low plastic SILT
Atterberg Limit
LL 57
PI 34
Classification
AASHTO:- A - 7 - 6

% COBBLE	% GRAVEL	% SAND	% FINE
-	2	12	87

REPORTED BY

APPROVED BY

Solomon Tib... Soil & Construction Materials Laboratory Head

AR♦CON Design-Build plc.

GEOTECHNICAL ENGINEERING SERVICE
P.O.Box 110246, Addis Ababa Ethiopia
Tel. +251 11 860 36 99, +251 11 860 37 83/84, Fax: +251 860 36 99
E-mail: ar-con@ethionet.et

CLIENT	:	Michael Ababu
PROJECT	:	Kality Ring Road Rigid Pavement
TEST OBJECT	:	Disturbed soil
LAB. NO	:	36664/2017
SAMPLE SOURCE	:	Sub grade material(Sample - 02)
SAMPLE DEPTH(m)	:	1.40
TEST FOR	:	Sieve Analysis(AASHTO T- 88)
REPORTED ON	:	03/05/2017

SPECIFIC GRAVITY TEST REPORT

Sample ID	Depth , @m	GS
Sample no 1	1.6	2.67
Sample no 2	1.4	2.72
Sample no 3	1.5	2.73

REPORTED BY

APPROVED BY

Solomon Tibebu Chekol
Soil & Construction Materials
Laboratory Head

AR◆CON Design-Build plc.

GEOTECHNICAL ENGINEERING SERVICE

P.O.Box 110246, Addis Ababa Ethiopia

Tel., +251 11 860 36 99, +251 11 860 37 83/84, Fax: +251 860 36 99

CLIENT	:	Michael Ababu
PROJECT	:	Kality Ring Road Rigid Pavement
TEST OBJECT	:	Disturbed soil
LAB. NO	:	36658/2017
SAMPLE SOURCE	:	Refer from the above table
SAMPLE DEPTH(m)	:	Refer from the above table
TEST FOR	:	SPECIFIC GRAVITY
REPORTED ON	:	03/05/2017

MOISTUER CONTENT TEST REPORT

Sample ID	Depth , @m	NMC , %
Sample no 1	1.6	20.86
Sample no 2	1.4	33.63
Sample no 3	1.5	30.52

REPORTED BY

APPROVED BY

Solomon Tibebu Chekol
Soil & Construction Materials Laboratory Head

AR CON Design-Build plc.

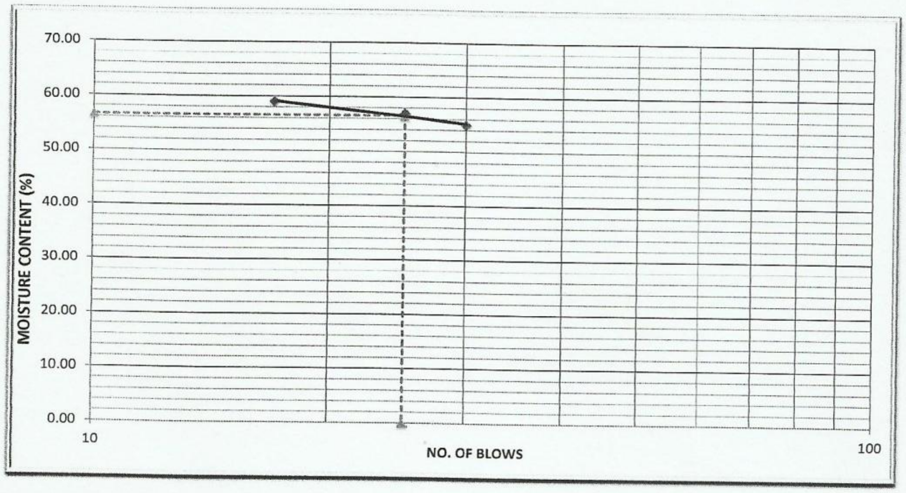
GEOTECHNICAL ENGINEERING SERVICE

P.O.Box 110246, Addis Ababa Ethiopia

Tel., +251 11 860 36 99, +251 11 860 37 83/84, Fax: +251 860 36 99

CLIENT	:	Michael Ababu
PROJECT	:	Kality Ring Road Rigid Pavement
TEST OBJECT	:	Undisturbed soil
LAB. NO	:	36659/2017
SAMPLE SOURCE	:	Refer from the above table
SAMPLE DEPTH(m)	:	Refer from the above table
TEST FOR	:	MOISTUER CONTENT
REPORTED ON	:	03/05/2017

LIQUID AND PLASTIC LIMITS TEST REPORT



	LIQUID LIMIT			PLASTIC LIMIT	
No. Blows	30	25	17		
Wt. wet soil (g.)	18.03	17.41	17.44	5.71	4.79
Wt. dry soil (g.)	11.63	11.09	10.97	4.67	3.85
Moisture content (%)	55.03	56.99	58.98	22.27	24.45
				AV. PL (%)	23.4

Liquid Limit LL(%)	Plastic Limit PL(%)	Plasticity Index PI	WET SEIVE ANALYSIS, % PASS		
			2mm	0.425mm	0.075mm
56.99	23.36	33.63	100.00	88.37	86.86

REPORTED BY

APPROVED BY

Solomon Tibebu Chekol
Soil & Construction Materials
Laboratory Head

AR♦CON Design-Build plc.

GEOTECHNICAL ENGINEERING SERVICE

P.O.Box 110246, Addis Ababa Ethiopia

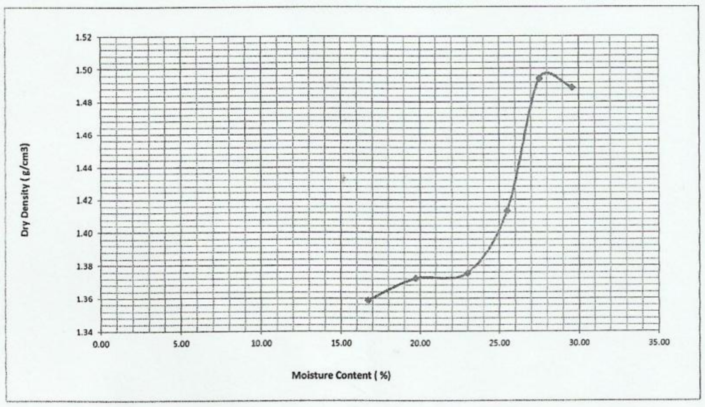
Tel., +251 11 860 36 99, +251 11 860 37 83/84, Fax: +251 860 36 99

CLIENT	:	Michael Ababu
PROJECT	:	Kality Ring Road Rigid Pavement
TEST OBJECT	:	Disturbed soil
LAB. NO	:	36665/2017
SAMPLE SOURCE	:	Sub grade material(Sample - 02)
SAMPLE DEPTH(m)	:	1.40
TEST FOR	:	Atterberg Limit
REPORTED ON	:	03/05/2017

COMPACTION TEST RESULTS

(AASHTO DESIGNATION T-99)

Tri No	1	2	3	4	5.00	6
Wet soil(g)	1497	1551	1597	1674	1799	1821
Bulk density (g/cm3)	1.585805085	1.643008475	1.691737288	1.773305085	1.905720339	1.929025424
Moisture content determination						
Wet soil(g)	524	443	551	640	727	819
Dry soil(g)	449	370	448	510	570	632
Moisture cont.(%)	16.70	19.73	22.99	25.49	27.54	29.59
Dry Density(g/cm3)	1.36	1.37	1.38	1.41	1.49	1.49



OMC=	25.6 %
MDD=	1.4885 gm/cm3

REPORTED BY

APPROVED BY

Solomon Tibebu Chekol
Soil & Construction Materials
Laboratory Head

AR◆CON Design-Build plc.

GEOTECHNICAL ENGINEERING SERVICE

P.O.Box 110246, Addis Ababa Ethiopia

Tel., +251 11 860 36 99, +251 11 860 37 83/84, Fax: +251 860 36 99

CLIENT	:	Michael Ababu
PROJECT	:	Kality Ring Road Rigid Pavement
TEST OBJECT	:	Disturbed soil
LAB. NO	:	36666/2017
SAMPLE SOURCE	:	Sub grade material(Sample - 02)
SAMPLE DEPTH(m)	:	1.40
TEST FOR	:	Compaction
REPORTED ON	:	03/05/2017

1. Specimen Data

Density				
	5 Layer		✓	
	3 Layer			
No. of Blows / Layer	10 B	30 B	65 B
Mass of Mold, gm	6310	6325	6359
Mass of Mold + Wet Soil, gm	10090	10276	10530
Mass of Wet Soil, gm	3780	3951	4171
Volume of Mold, cm^3	2124	2124	2124
Bulk Density, g/cm^3	1.78	1.86	1.96
Moisture Content, %		27.87	
Dry Density, g/cm^3	1.39	1.45	1.54

Moisture Content	
Container No.	~
Mass of Container, gm	30
Mass of Cont + Wet Soil, gm	108
Mass of Container + Dry Soil, gm	91
Mass of Water, gm	17
Mass of Dry Soil, gm	61
Moisture Content, %	27.87

CALIBRATION/STANDARD DATA		
	Rammer 2.5kg	
	Rammer 4.5kg	✓
	Volume, cm^3	2124
	Height(Hs),mm	116.43
	Swell Dia. Sens.	0.01
	Piston Area, cm^2	1.935
	Ring No.	-
	Ring Factor/ Calibration	0.02557 KN/div

Standar Load		
@2.54mm	13.2	KN
@5.08mm	20	KN

2. Swell Data

Surcharge Weight	Swell Data			
	Number of Blows	10B	30B	65B
4.5 kg	Reading Before Soaking, mm	67	110	155
	Reading After 96hr's Soaking, mm	284	303	327
	Swell, %	1.86	1.66	1.48

3. Penetration Data

Penetration (mm)	Penetration Test Data											
	D.R (div)	Load (KN)	Corr. Load (KN)	CBR %	D.R (div)	Load (KN)	Corr. Load (KN)	CBR %	D.R (div)	Load (KN)	Corr. Load (KN)	CBR %
0.00	0	0.00			0	0.00			0	0.00		
0.64	4	0.10			6	0.15			7	0.18		
1.27	5	0.13			8	0.20			9	0.23		
1.91	6.5	0.17			9	0.23			11	0.27		
2.54	8	0.20	0.20	1.55	11	0.28	0.28	2.13	13	0.33	0.33	2.52
3.81	10.5	0.27			12.5	0.32			15	0.38		
5.08	13	0.33	0.33	1.66	17	0.43	0.43	2.17	20	0.51	0.51	2.56
7.62	0	0.00			0	0.00			0	0.00		
10.20												

REPORTED BY

APPROVED BY

AR◆CON

Solomon Tibebu Chekol
Construction Materials
Laboratory Head

AR◆CON Design-Build plc.

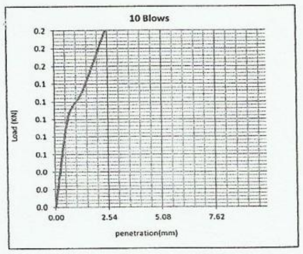
GEOTECHNICAL ENGINEERING SERVICE

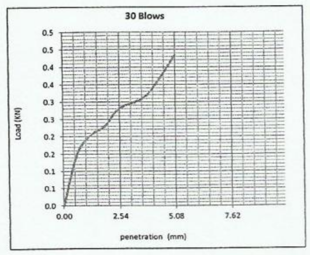
P.O.Box 110246, Addis Ababa Ethiopia

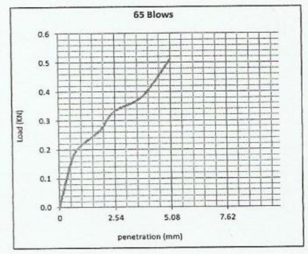
Tel., +251 11 860 36 99, +251 11 860 37 83/84, Fax: +251 860 36 99

CLIENT	:	Michael Ababu
PROJECT	:	Kality Ring Road Rigid Pavement
TEST OBJECT	:	Disturbed soil
LAB. NO	:	36667/2017
SAMPLE SOUR(	:	Sub grade material(Sample - 02)
SAMPLE DEPTH	:	1.40
TEST FOR	:	CBR
REPORTED ON	:	03/05/2017

Load vs Penetration Curves

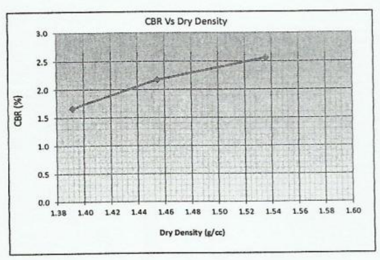






Blows	LOAD (KN)		CBR(%)	
	2.54mm	5.98mm	2.54mm	5.08mm
10	0.20	0.33	1.55	1.66
30	0.28	0.43	2.13	2.17
65	0.33	0.51	2.52	2.56

Blows	Dry Density g/cm³	CBR %
10	1.39	1.66
30	1.45	2.17
65	1.54	2.56



Proctor MDD, g/cc	95% MDD, g/cc	CBR @95%MDD %
1.4885	1.414	1.85

REPORTED BY

APPROVED BY

AR♦CON Design-Build plc.

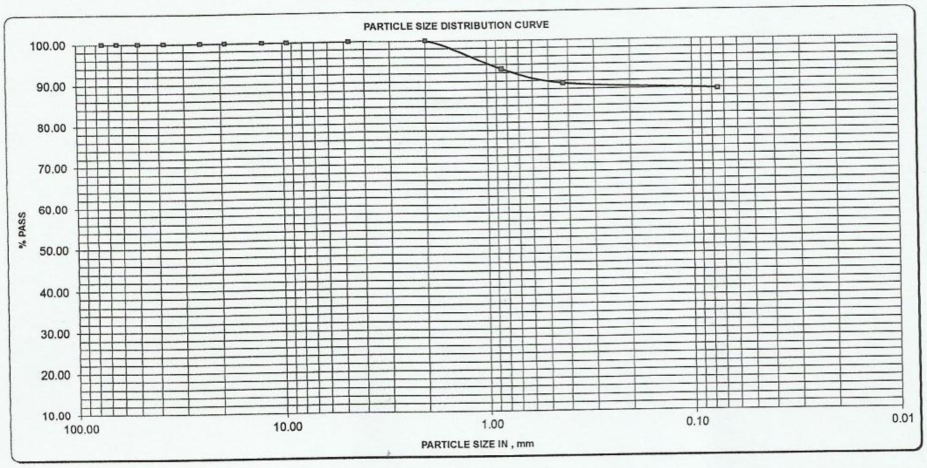
GEOTECHNICAL ENGINEERING SERVICE

P.O.Box 110246, Addis Ababa Ethiopia

Tel., +251 11 860 36 99, +251 11 860 37 83/84, Fax: +251 860 36 99

CLIENT	:	Michael Ababu
PROJECT	:	Kality Ring Road Rigid Pavement
TEST OBJECT	:	Disturbed soil
LAB. NO	:	36667/2017
SAMPLE SOUR(	:	Sub grade material(Sample - 02)
SAMPLE DEPTH	:	1.40
TEST FOR	:	CBR
REPORTED ON	:	03/05/2017

PARTICLE SIZE DISTRIBUTION REPORT



SIEVE SIZE (MM.)	% PASSED
63.500	100
50.000	100
37.500	100
25.000	100
19.000	100
12.500	100
9.500	100
4.750	100
2.000	100
0.850	93
0.425	89

Soil Description
Low plastic SILT
Atterberg Limit
LL 57
PI 31
Classification
USCS :-
AASHTO:- A - 7 - 6

% COBBLE	% GRAVEL	% SAND	% FINE
-	2	11	88

REPORTED BY

APPROVED BY

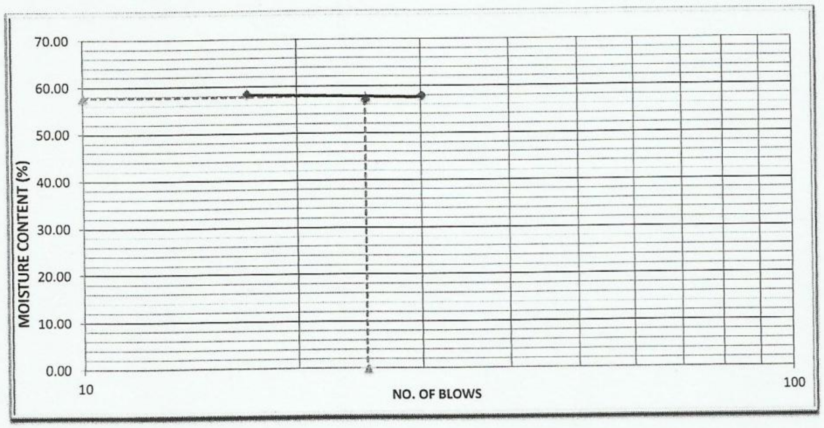
Michael Ababu Chekol
Construction Materials Laboratory Head

AR♦CON Design-Build plc.
አር ኮን ዲዛይን ቢልድ ኃ/የተ/የግ/ማ

GEOTECHNICAL ENGINEERING SERVICE
P.O.Box 110246, Addis Ababa Ethiopia
Tel.,+251 11 860 36 99, +251 11 860 37 83/84, Fax: +251 860 36 99
E-mail: ar-con@ethionet.et

CLIENT	:	Michael Ababu
PROJECT	:	Kality Ring Road Rigid Pavement
TEST OBJECT	:	Disturbed soil
LAB. NO	:	36668/2017
SAMPLE SOURCE	:	Sub grade material(Sample - 03)
SAMPLE DEPTH(m)	:	1.50
TEST FOR	:	Sieve Analysis(AASHTO T- 88)
REPORTED ON	:	03/05/2017

LIQUID AND PLASTIC LIMITS TEST REPORT



	LIQUID LIMIT			PLASTIC LIMIT	
No. Blows	30	25	17		
Wt. wet soil (g.)	26.51	26.70	28.20	5.88	5.71
Wt. dry soil (g.)	16.79	16.99	17.80	4.75	4.41
Moisture content (%)	57.89	57.15	58.43	23.79	29.48
				AV. PL (%)	26.6

Liquid Limit LL(%)	Plastic Limit PL(%)	Plasticity Index PI	WET SEIVE ANALYSIS, % PASS		
			2mm	0.425mm	0.075mm
57.15	26.63	30.52	100.00	89.38	87.77

REPORTED BY

APPROVED BY

AR♦CON Design-Build plc.

GEOTECHNICAL ENGINEERING SERVICE

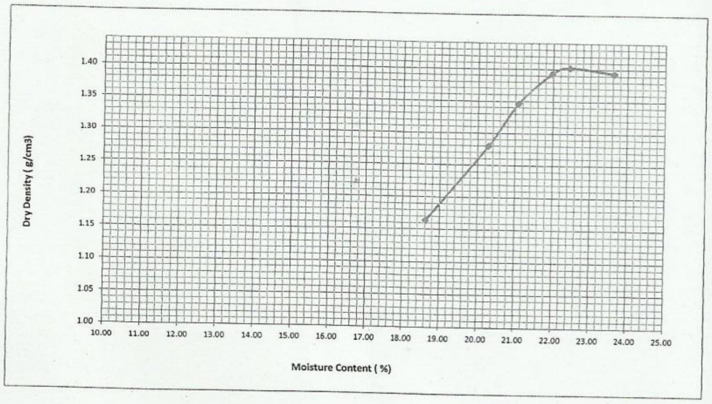
P.O.Box 110246, Addis Ababa Ethiopia

Tel., +251 11 860 36 99, +251 11 860 37 83/84, Fax: +251 860 36 99

CLIENT	:	Michael Ababu
PROJECT	:	Kality Ring Road Rigid Pavement
TEST OBJECT	:	Disturbed soil
LAB. NO	:	36669/2017
SAMPLE SOURCE	:	Sub grade material(Sample - 03)
SAMPLE DEPTH(m)	:	1.50
TEST FOR	:	Atterberg Limit
REPORTED ON	:	03/05/2017

COMPACTION TEST RESULTS
(AASHTO DESIGNATION T-99)

Tri No	1	2	3	4	5.00	6
Wet soil(g)	1303	1453	1539	1603	1621	1626
Bulk density (g/cm3)	1.38029661	1.539194915	1.63029661	1.69809322	1.717161017	1.722457627
Moisture content determination						
Wet soil(g)	548	421	534	633	720	790
Dry soil(g)	462	350	441	519	588	639
Moisture cont.(%)	18.61	20.29	21.09	21.97	22.45	23.63
Dry Density(g/cm3)	1.16	1.28	1.35	1.39	1.40	1.39



OMC=	22.44 %
MDD=	1.405 gm/cm3

REPORTED BY

APPROVED BY

AR◆CON Design-Build plc.

GEOTECHNICAL ENGINEERING SERVICE

P.O.Box 110246, Addis Ababa Ethiopia

Tel., +251 11 860 36 99, +251 11 860 37 83/84, Fax: +251 860 36 99

CLIENT	:	Michael Ababu
PROJECT	:	Kality Ring Road Rigid Pavement
TEST OBJECT	:	Disturbed soil
LAB. NO	:	36670/2017
SAMPLE SOURCE	:	Sub grade material(Sample - 03)
SAMPLE DEPTH(m)	:	1.50
TEST FOR	:	Compaction
REPORTED ON	:	03/05/2017

1. Specimen Data

Density				
	5 Layer		✓	
	3 Layer			
No. of Blows / Layer	10 B	30 B	65 B	
Mass of Mold, gm	6317	6276	6346	
Mass of Mold + Wet Soil, gm	9461	9669	10121	
Mass of Wet Soil, gm	3144	3393	3775	
Volume of Mold, cm^3	2124	2124	2124	
Bulk Density, g/cm^3	1.48	1.60	1.78	
Moisture Content, %		29.49		
Dry Density, g/cm^3	1.14	1.23	1.37	

Moisture Content	
Container No.	~
Mass of Container, gm	17
Mass of Cont + Wet Soil, gm	118
Mass of Container + Dry Soil, gm	95
Mass of Water, gm	23
Mass of Dry Soil, gm	78
Moisture Content, %	29.49

CALIBRATION/STANDARD DATA		
	Rammer 2.5kg	
	Rammer 4.5kg	✓
	Volume,cm^3	2124
	Height(Hs),mm	116.43
	Swell Dia. Sens.	0.01
	Piston Area, cm^2	1.935
	Ring No.	-
	Ring Factor/ Calibration	0.02557 KN/div
Standar Load		
@2.54mm	13.2	KN
@5.08mm	20	KN

2. Swell Data

Surcharge Weight	Swell Data			
	Number of Blows	10B	30B	65B
4.5 kg	Reading Before Soaking, mm	127	158	135
	Reading After 96hr's Soaking, mm	367	370	340
	Swell, %	2.06	1.82	1.76

3. Penetration Data

Penetration (mm)	Penetration Test Data											
	D.R (div)	Load (KN)	Corr. Load (KN)	CBR %	D.R (div)	Load (KN)	Corr. Load (KN)	CBR %	D.R (div)	Load (KN)	Corr. Load (KN)	CBR %
0.00	0.00	0.00			0	0.00			0	0.00		
0.64	4.00	0.10			5	0.13			6	0.14		
1.27	4.50	0.12			6	0.15			6	0.16		
1.91	5.50	0.14			7.5	0.19			8	0.19		
2.54	7.00	0.18	0.18	1.36	8	0.20	0.20	1.55	9	0.23	0.23	1.74
3.81	10.00	0.26			10	0.26			10	0.26		
5.08	12.00	0.31	0.31	1.53	13	0.33	0.33	1.66	14	0.36	0.36	1.79
7.62	0.00	0.00			0	0.00			0	0.00		
10.20												

REPORTED BY

APPROVED BY

ሰለሞን ጥበ...
Solomon Tibebu
Soil & Construction Materials Laboratory

AR•CON Design-Build plc.

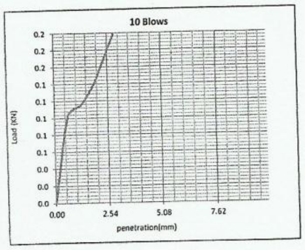
GEOTECHNICAL ENGINEERING SERVICE

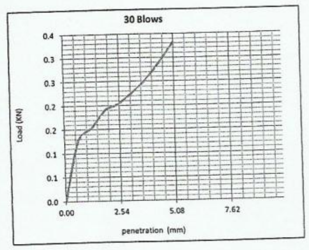
P.O.Box 110246, Addis Ababa Ethiopia

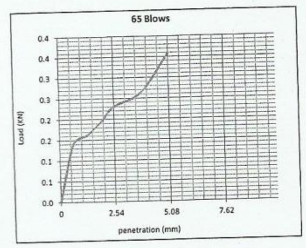
Tel., +251 11 860 36 99, +251 11 860 37 83/84, Fax: +251 860 36 99

CLIENT	:	Michael Ababu
PROJECT	:	Kality Ring Road Rigid Pavement
TEST OBJECT	:	Disturbed soil
LAB. NO	:	36671/2017
SAMPLE SOUR(	:	Sub grade material(Sample - 03)
SAMPLE DEPTH	:	1.50
TEST FOR	:	CBR
REPORTED ON	:	03/05/2017

Load vs Penetration Curves

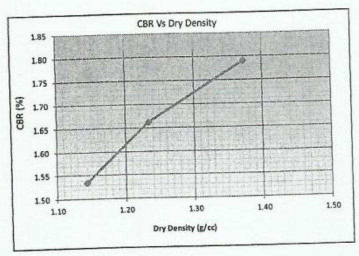






Blows	LOAD (KN)		CBR(%)	
	2.54mm	5.98mm	2.54mm	5.08mm
10	0.18	0.31	1.36	1.53
30	0.20	0.33	1.55	1.66
65	0.23	0.36	1.74	1.79

Blows	Dry Density g/cm³	CBR %
10	1.14	1.53
30	1.23	1.66
65	1.37	1.79



Proctor MDD, g/cc	95% MDD, g/cc	CBR @95%MDD %
1.41	1.33	1.76

REPORTED BY

APPROVED BY

AR◆CON Design-Build plc.

GEOTECHNICAL ENGINEERING SERVICE

P.O.Box 110246, Addis Ababa Ethiopia

Tel., +251 11 860 36 99, +251 11 860 37 83/84, Fax: +251 860 36 99

CLIENT	:	Michael Ababu
PROJECT	:	Kality Ring Road Rigid Pavement
TEST OBJECT	:	Disturbed soil
LAB. NO	:	36671/2017
SAMPLE SOUR(	:	Sub grade material(Sample - 03)
SAMPLE DEPTH	:	1.50
TEST FOR	:	CBR
REPORTED ON	:	03/05/2017